OUTER BORDERLAND PROVINCE

by Frank W. Victor

LOCATION

The Outer Borderland province is located offshore southern California from the Channel Islands (on the north) to the U.S.-Mexico maritime boundary (on the south). The province is bounded on the west by the approximate base of the continental slope; to the east, it is bounded by the Santa Cruz-Catalina ridge and the Thirtymile bank (fig. 114).

This Federal offshore assessment province encompasses several geologic basins and areas. Some of these areas contain appreciable sections of sedimentary rock and may have petroleum potential. These areas include the Santa Cruz basin, Santa Rosa area,

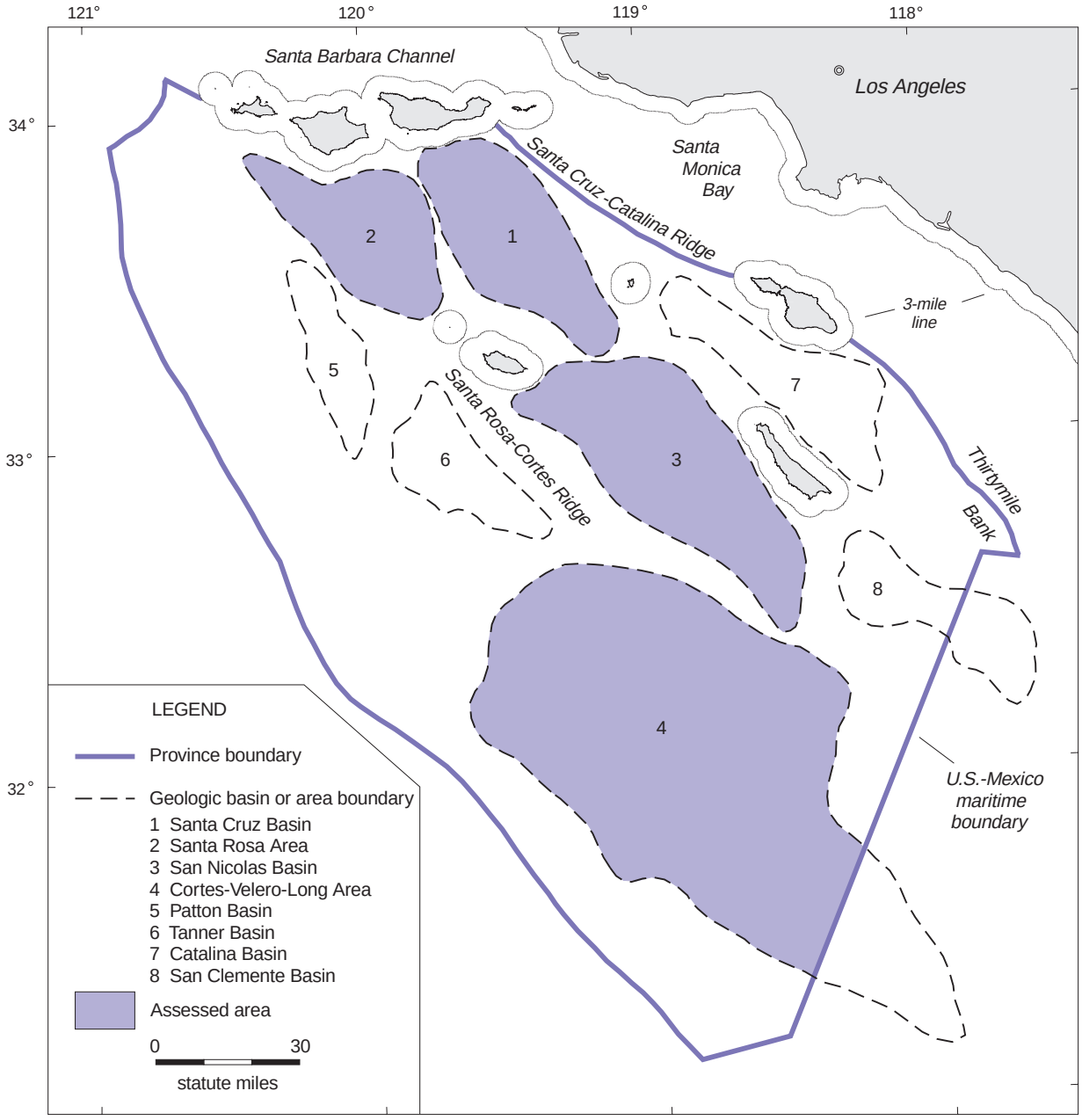

Figure 114. *Map of the Outer Borderland province showing geologic basins and areas, and assessed areas.*

San Nicolas basin, Cortes basin, Velero basin, and Long basin. The Santa Cruz basin and Santa Rosa area have been combined as a single assessment area due to the continuous extent of Paleogene and Cretaceous strata. Similarly, the Cortes, Velero, and Long basins have been combined as a single assessment area due to the nearly continuous extent of Paleogene strata and lack of definitive basin boundaries.

A number of the geologic basins and areas in the province lack an appreciable stratigraphic section and, therefore, probably lack sufficient petroleum source rock, thermal history, and reservoir rock; some of these areas are virtually devoid of traps. As a result, they are expected to have negligible petroleum potential and have not been formally assessed. These areas include the Patton basin, Tanner basin, Catalina basin, and San Clemente basin.

GEOLOGIC SETTING

Upper Cretaceous and Tertiary rocks are present in most of the geologic basins and areas in the province. Generally, these areas have been relatively "sediment starved" and contain much thinner Neogene stratigraphic sections than those in the Inner Borderland province.

Many of the basin geometries in this province formed during the Miocene as the result of extension and rotation of the continental borderland. The dominant structural trend in most of the basins is northwest-southeast. With the exception of the Santa Cruz and San Nicolas basins, in which late-stage compression has produced reverse faulting, most of the faults in the province are normal faults that developed in response to extension.

EXPLORATION

Although a number of seismic-reflection surveys have been recorded within the province, very limited exploratory drilling has taken place. A deep stratigraphic test well (OCS-CAL 75-70 No. 1) was drilled on Cortes bank in 1975 (Paul and others, 1976). In addition, nine exploratory oil and gas wells have been drilled from 1977 through 1983. They include one well south of Santa Rosa Island, one well on the Santa Cruz-Catalina ridge (northwest of Santa Barbara Island), and seven wells on Dall and Tanner banks (at the southern end of the Santa Rosa-Cortes ridge). Unfortunately, most of these wells are located in structurally uplifted areas and are of limited use in interpreting the nature of strata within the geologic basins and areas. No appreciable shows of hydrocarbons were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in some of the wells.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of the total volume of undiscovered conventionally recoverable resources in the province have been developed by statistically aggregating the constituent assessment area estimates. As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the Outer Borderland province is estimated to be 1.40 Bbbl of oil and 2.79 Tcf of associated gas (mean estimates). The low, mean, and high estimates of resources in the province are listed in table 40 and illustrated in figure 115.

Undiscovered Economically Recoverable Resources

Estimates of the total volume of undiscovered conventionally recoverable resources in the province that may be economically recoverable under various economic scenarios have been developed by statistically aggregating the constituent assessment area estimates. As a result of this assessment, 62 MMbbl of oil and 104 Bcf of associated gas are estimated to be economically recoverable from the Outer Borderland province under economic conditions existing as of this assessment (i.e., the $18-per-barrel economic scenario) (table 41). Larger volumes of resources are expected to be economically recoverable under increasingly favorable economic conditions (fig. 116).

Total Resource Endowment

No accumulations of resources have been discovered in the province. Therefore, the aforementioned estimates of undiscovered conventionally recoverable resources compose the estimated total resource endowment of the province.

Table 40. *Estimates of undiscovered conventionally recoverable oil and gas resources in the Outer Borderland province as of January 1, 1995, by assessment area. All estimates are risked values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.*

Assessment Area	Oil (Bbbl)			Gas (Tcf)			BOE (Bbbl)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Santa Cruz-Santa Rosa Area	0	0.44	0.93	0	0.78	1.85	0	0.58	1.24
San Nicolas Basin	0	0.55	1.18	0	0.91	2.42	0	0.71	1.58
Cortes-Velero-Long Area	0	0.41	1.20	0	1.10	3.49	0	0.61	1.80
Total Province	*0.63*	*1.40*	*2.56*	*0.98*	*2.79*	*5.89*	*0.82*	*1.89*	*3.56*

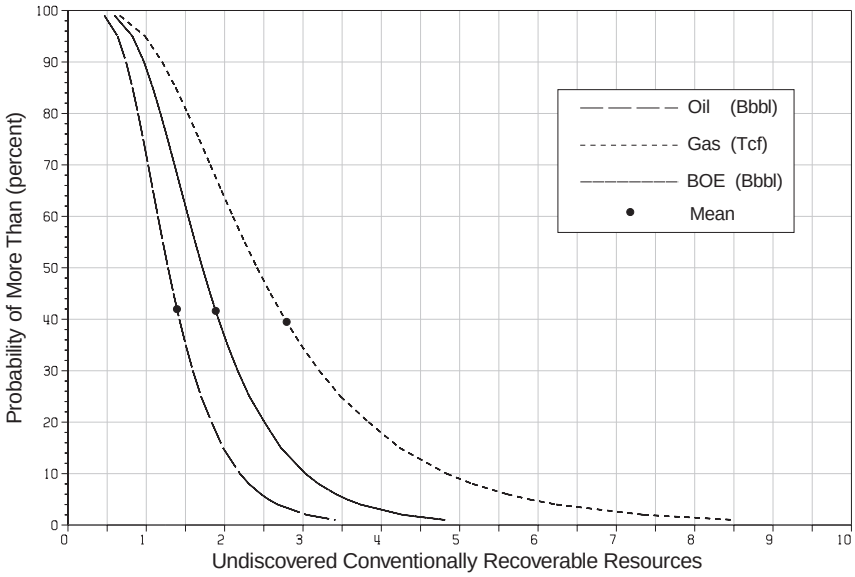

Figure 115. *Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the Outer Borderland province.*

ACKNOWLEDGMENTS

The extensive work of Jack Vedder was an important source of information for this assessment of the Outer Borderland province. Acknowledgment is also due to James Galloway, Bill Kou, Robert MacDonald, and Ken Piper who performed seismic interpretative mapping in various areas of the province.

ADDITIONAL REFERENCES

Crouch and Suppe, 1993
McLean and Wiley, 1987
Vedder, 1987

Table 41. *Estimates of undiscovered economically recoverable oil and gas resources in the Outer Borderland province as of January 1, 1995 for three economic scenarios, by assessment area. All estimates are risked mean values. The $18-per-barrel scenario is based on prices of $18 per bbl of oil and $2.11 per Mcf of gas; the $25-per-barrel scenario is based on prices of $25 per bbl of oil and $2.94 per Mcf of gas; the $50-per-barrel scenario is based on prices of $50 per barrel of oil and $5.87 per Mcf of gas. Some total values may not equal the sum of the component values due to independent rounding.*

Assessment Area	$18-per-barrel Scenario			$25-per-barrel Scenario			$50-per-barrel Scenario		
	Oil (Bbbl)	Gas (Tcf)	BOE (Bbbl)	Oil (Bbbl)	Gas (Tcf)	BOE (Bbbl)	Oil (Bbbl)	Gas (Tcf)	BOE (Bbbl)
Santa Cruz-Santa Rosa Area	<0.01	0.01	0.01	0.10	0.18	0.13	0.33	0.58	0.43
San Nicolas Basin	0.06	0.09	0.07	0.20	0.34	0.26	0.40	0.67	0.52
Cortes-Velero-Long Area	0	0	0	<0.01	<0.01	<0.01	0.21	0.57	0.31
Total Province	*0.06*	*0.10*	*0.08*	*0.30*	*0.52*	*0.40*	*0.94*	*1.83*	*1.27*

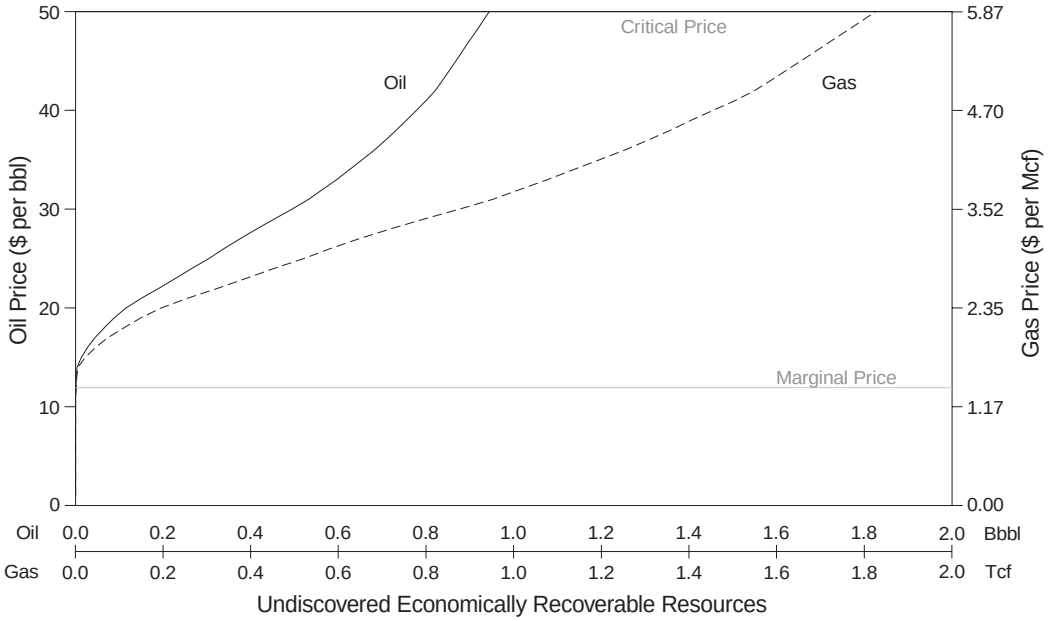

Figure 116. *Price-supply plot of estimated undiscovered economically recoverable resources of the Outer Borderland province.*

SANTA CRUZ-SANTA ROSA AREA

by Frank W. Victor

LOCATION

The Santa Cruz-Santa Rosa assessment area occupies the northern portion of the Outer Borderland province (fig. 114). The assessment area comprises two geologic subareas, the Santa Cruz basin and the Santa Rosa area. These areas have been combined as a single assessment area due to the continuous extent of Paleogene and Cretaceous strata.

The Santa Cruz basin is located immediately south of Santa Cruz Island; it is bounded on the east by the Santa Cruz-Catalina ridge and on the west by an unnamed paleohigh that merges with the Santa Rosa-Cortes ridge to the south (fig. 117). This northwest-trending basin extends approximately 55 miles in length and averages 20 miles in width. It encompasses an area of approximately 1,000 square miles. Water depth within the basin averages about 3,000 feet.

The Santa Rosa area is located south of Santa Rosa Island. The area extends approximately 30 miles west from the Santa Cruz basin and extends south to Begg Rock (fig. 117). It is approximately 50 miles long and from 5 to 25 miles wide and encompasses an area of approximately 900 square miles. Water depth within the area ranges from 500 to 3,500 feet.

GEOLOGIC SETTING

The Santa Cruz basin is an elongate, northwest-trending basin, which contains up to approximately 9,000 feet of Upper Cretaceous through Quaternary strata[16] (fig. 118). The basin is asymmetrical with the depocenter located in the eastern half of the basin. Post-Miocene compression, primarily from the west, has created a number of asymmetrical, reverse-fault-bounded anticlines in the eastern part of the basin. These structures are evident on seismic-reflection

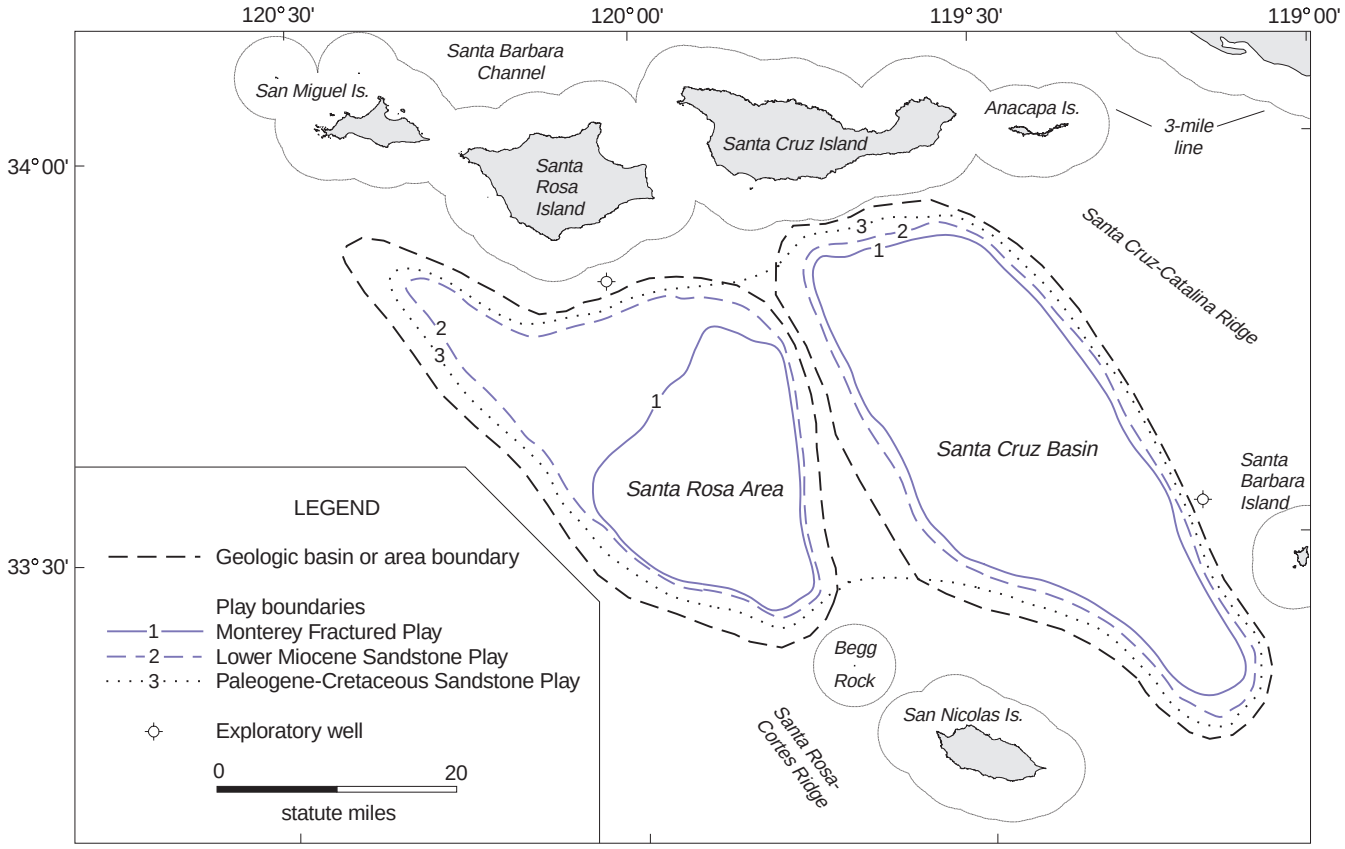

Figure 117. *Map of the Santa Cruz-Santa Rosa assessment area showing the geologic basin and area, petroleum geologic plays, and wells.*

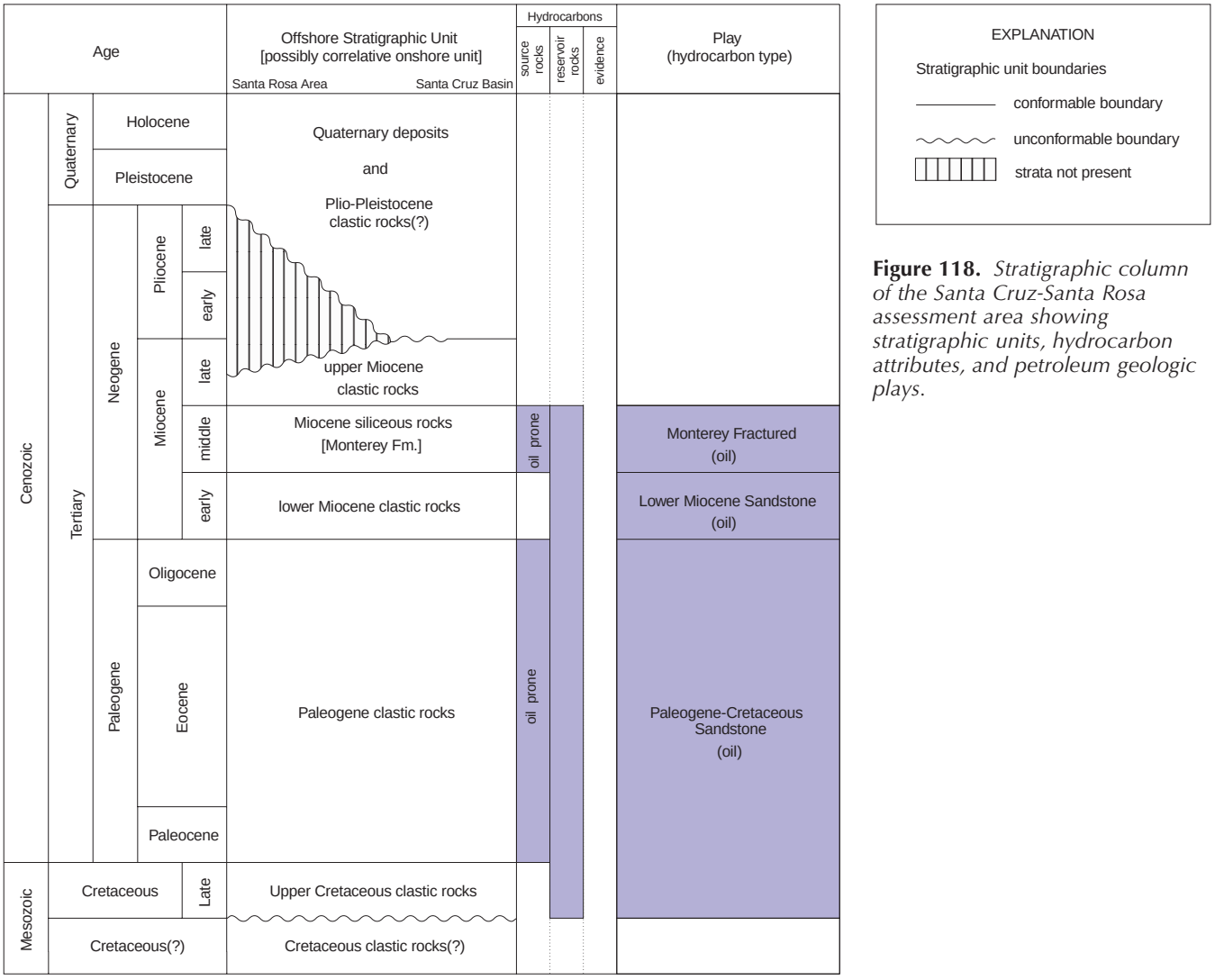

Figure 118. *Stratigraphic column of the Santa Cruz-Santa Rosa assessment area showing stratigraphic units, hydrocarbon attributes, and petroleum geologic plays.*

profiles and are numerous and large enough to trap significant quantities of oil and gas.

The Santa Rosa area is a broad depositional area (i.e., not a confined basin), which contains up to approximately 6,000 feet of Upper Cretaceous, Paleogene, and Miocene clastic strata[16] (fig. 118). Upper Miocene and younger strata are very thin or nonexistent within the area due to extremely low depositional rates and uplift and erosion. A number of relatively small, low-relief structures, which may contain oil and gas, exist in the area.

EXPLORATION

No exploratory wells have been drilled within the Santa Cruz-Santa Rosa assessment area; one well (OCS-P 0289 #1) was drilled immediately east of the Santa Cruz basin, and another well (OCS-P 0245 #1) was drilled immediately north of the Santa Rosa area. In addition, a number of moderate- to high-quality seismic-reflection surveys have been recorded in both areas.

The adjacent wells penetrated lower Miocene, Paleogene, and Cretaceous strata. Most middle Miocene and younger strata have been eroded from the uplifted areas in which the wells were drilled; however, middle Miocene and younger strata are present in the Santa Cruz-Santa Rosa assessment

[16] Descriptions of the age and lithology of stratigraphic units in the Santa Cruz-Santa Rosa assessment area are based on inference (rather than direct evidence) because no wells have been drilled within the area. Individual stratigraphic units are inferred to exist based on seismic-stratigraphic extrapolation of units that have been penetrated in wells in the Outer Borderland province (see this report); analog data from these wells have been used in the assessment of plays in the Santa Cruz-Santa Rosa assessment area.

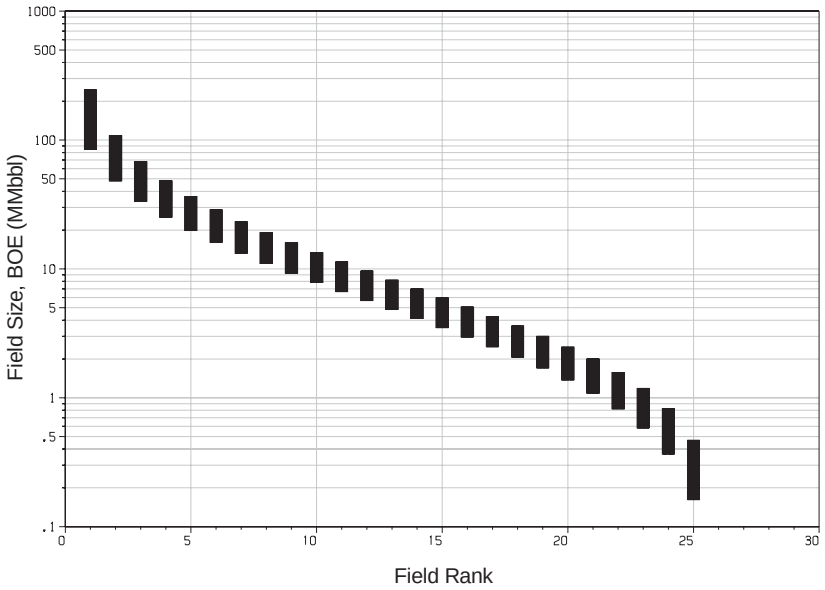

Figure 119. *Field-size rank plot of estimated undiscovered conventionally recoverable resources of the Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered fields are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile value of a probability distribution, respectively.*

area. The approximate geologic age of these undrilled stratigraphic units is estimated based on seismic-stratigraphic extrapolation of older strata penetrated by the wells.

No appreciable shows of oil or gas were encountered in either of the adjacent wells; however, weak indications of gas were encountered in one well.

PLAYS

Five petroleum geologic plays have been defined in the Santa Cruz-Santa Rosa assessment area (fig. 118). The plays were defined on the basis of reservoir rock stratigraphy. The plays (and corresponding reservoir rocks) consist of two Monterey Fractured plays (fractured siliceous rocks), two Lower Miocene Sandstone plays (clastic rocks), and one Paleogene-Cretaceous Sandstone play (clastic rocks).

The Monterey Fractured and Lower Miocene Sandstone plays are confined to the Santa Cruz basin proper and the Santa Rosa area proper and have been individually assessed in each area. The Paleogene-Cretaceous Sandstone play exists within and between both areas and has been assessed as a single play.

All of the plays in the Santa Cruz-Santa Rosa assessment area are considered to be conceptual plays based on the absence of directly detected hydrocarbons within the play areas. This is presumed to be a consequence of the location and limited number of the wells rather than a lack of geological conditions conducive to hydrocarbon accumulation.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Play-specific estimates of undiscovered conventionally recoverable resources have been developed using the subjective assessment method, and these estimates have been statistically aggregated to estimate the total volume of resources in the assessment area. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the Santa Cruz-Santa Rosa assessment area is estimated to be 438 MMbbl of oil and 782 Bcf of associated gas (mean estimates). This volume may exist in 25 fields with sizes ranging from approximately 160 Mbbl to 245 MMbbl of combined oil-equivalent resources (fig. 119). The majority of these resources (64 percent on a combined oil-equivalence basis) are estimated to exist in the Santa Cruz basin. The low, mean, and high estimates of resources in the assessment area are listed in table 42 and illustrated in figure 120.

Undiscovered Economically Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the assessment area that may be economically recoverable under various economic scenarios have been developed using the economic assessment method. Select data used to develop the resource estimates are shown in appendix D.

Table 42. *Estimates of undiscovered conventionally recoverable oil and gas resources in the Santa Cruz-Santa Rosa assessment area as of January 1, 1995, by play. All estimates are risked values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.*

Play	Oil (MMbbl)			Gas (Bcf)			BOE (MMbbl)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Santa Cruz Basin									
Monterey Fractured	0	194	445	0	227	555	0	234	540
Lower Miocene Sandstone	0	92	271	0	231	802	0	133	407
Santa Rosa Area									
Monterey Fractured	0	31	110	0	39	148	0	38	136
Lower Miocene Sandstone	0	30	132	0	79	440	0	44	213
Santa Cruz-Santa Rosa Area									
Paleogene-Cretaceous Sandstone	0	92	389	0	207	985	0	129	563
Total Assessment Area	*0*	*438*	*926*	*0*	*782*	*1,852*	*0*	*577*	*1,237*

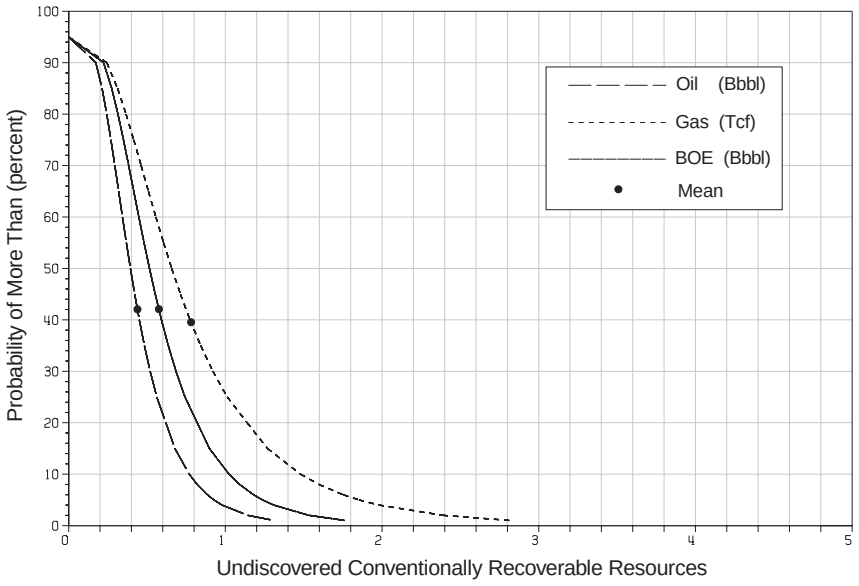

Figure 120. *Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the Santa Cruz-Santa Rosa assessment area.*

As a result of this assessment, 7 MMbbl of oil and 13 Bcf of associated gas are estimated to be economically recoverable from the Santa Cruz-Santa Rosa assessment area under economic conditions existing as of this assessment (i.e., the $18-per-barrel economic scenario) (table 43). Larger volumes of resources are expected to be economically recoverable under increasingly favorable economic conditions (fig. 121).

Total Resource Endowment

No accumulations of resources have been discovered in the assessment area. Therefore, the aforementioned estimates of undiscovered conventionally recoverable resources compose the estimated total resource endowment of the area.

Table 43. *Estimates of undiscovered economically recoverable oil and gas resources in the Santa Cruz-Santa Rosa assessment area as of January 1, 1995, by economic scenario. All estimates are risked mean values. The $18-per-barrel scenario is based on prices of $18 per bbl of oil and $2.11 per Mcf of gas; the $25-per-barrel scenario is based on prices of $25 per bbl of oil and $2.94 per Mcf of gas; the $50-per-barrel scenario is based on prices of $50 per barrel of oil and $5.87 per Mcf of gas.*

Economic Scenario	Oil (MMbbl)	Gas (Bcf)	BOE (MMbbl)
$18 per barrel	7	13	10
$25 per barrel	98	176	130
$50 per barrel	327	584	431

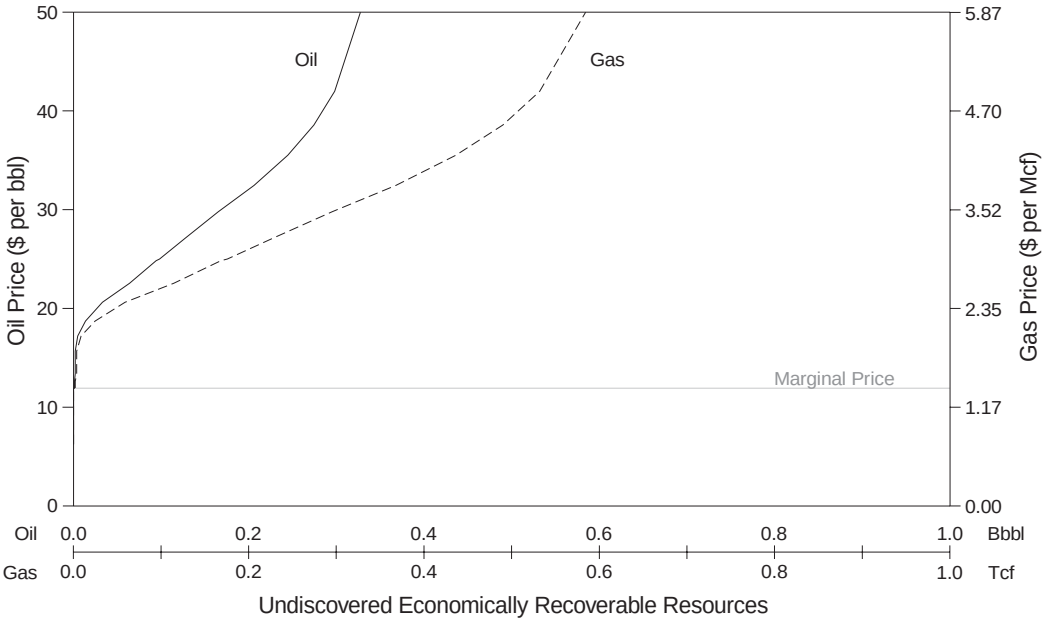

Figure 121. *Price-supply plot of estimated undiscovered economically recoverable resources of the Santa Cruz-Santa Rosa assessment area.*

MONTEREY FRACTURED PLAYS

PLAY DEFINITION

The Monterey Fractured plays of the Santa Cruz basin and the Santa Rosa area are conceptual plays consisting of accumulations of oil and associated gas in middle Miocene fractured siliceous rocks of the Monterey Formation. Because the plays are confined to the Santa Cruz basin proper and the Santa Rosa area proper (fig. 117), they have been individually assessed in each area.

The play exists over most of the Santa Cruz basin where it encompasses an area of about 700 square miles. The depth to reservoir rocks of the play in this basin ranges from 2,000 to 6,000 feet below the seafloor.

In the Santa Rosa area, the play is limited to the southeast part of the area, due to the limited original depositional extent and uplift and erosion of the Monterey Formation. The play encompasses an area of about 300 square miles; the depth to reservoir rocks of the play in this area ranges from 1,000 to 4,000 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The Monterey Formation is considered to be both petroleum source rock and reservoir rock for these plays (fig. 118) by analogy with Monterey rocks in the offshore Santa Barbara-Ventura and Santa Maria basins and the onshore San Joaquin basin. The type and amount of organic matter within Monterey rocks of the Santa Cruz basin and the Santa Rosa area are unknown; however, Monterey rocks in other California coastal basins are rich in organic matter, and similar rocks are presumed to exist in the Santa Cruz basin and the Santa Rosa area. The depth at which thermal maturation may have occurred in the Santa Cruz basin and the Santa Rosa area is also unknown. Monterey rocks are buried no more than 4,000 feet in the Santa Rosa area and may

not have been buried sufficiently to permit petroleum generation. Due to the moderately shallow depths of the potential reservoir rocks, the oil in these plays is predicted to be of moderate (less than 30 °API) gravity.

Potential reservoir rocks in these plays include middle Miocene fractured, siliceous and calcareous shales and cherts, and perhaps some basal clastic rocks of the Monterey Formation (fig. 118). Seismic profiles suggest that the Monterey section is thin in both the Santa Cruz basin and the Santa Rosa area; the thickness of these rocks is estimated to range from 300 to 1,000 feet. Diagenetic alteration, compression, and folding may have enhanced fracturing of the shales and cherts in the Santa Cruz basin. Monterey strata in these areas are expected to have reservoir characteristics similar to those in the offshore Santa Barbara-Ventura and Santa Maria basins.

The dominant trap type in these plays is expected to be the anticline.

EXPLORATION

Neither of the exploratory wells adjacent to the Santa Cruz-Santa Rosa assessment area penetrated rocks similar to those included in these plays. Middle Miocene strata presumably equivalent to the Monterey Formation are inferred to exist in both areas based on seismic-stratigraphic extrapolation of older strata from the adjacent wells and from the wells on Dall, Tanner, and Cortes banks.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in each play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in each play were estimated from seismic mapping. Conservatively reduced analog data from Monterey producing zones in the offshore Santa Barbara-Ventura and Santa Maria basins were used to estimate the oil recovery factor and gas-to-oil ratio for both plays.

As a result of this assessment, the play in the Santa Cruz basin is estimated to contain 194 MMbbl of oil and 227 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 46 pools with sizes ranging from approximately 230 Mbbl to 180 MMbbl of combined oil-equivalent resources (fig. 122). The low, mean, and high estimates of resources in the play are listed in table 42.

The play in the Santa Rosa area is estimated to contain 31 MMbbl of oil and 39 Bcf of associated gas

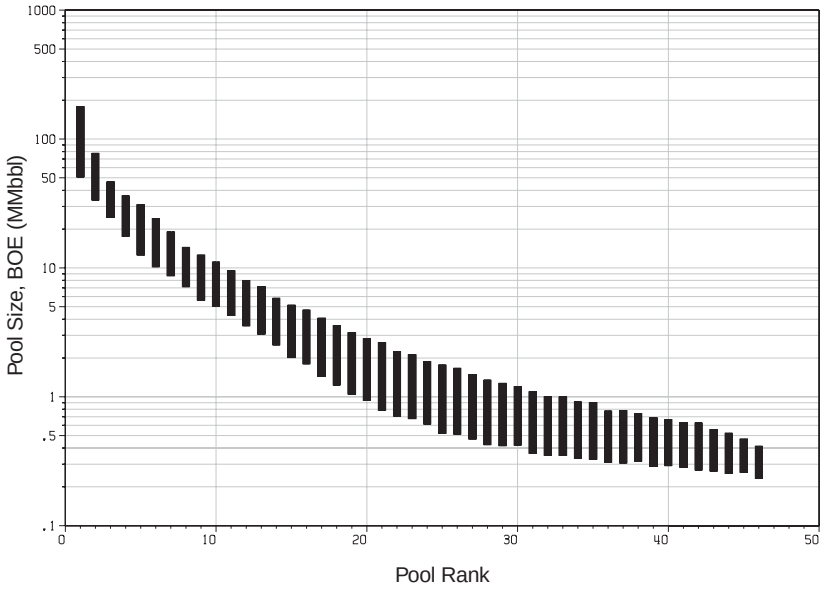

Figure 122. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Monterey Fractured play, Santa Cruz Basin subarea of the Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

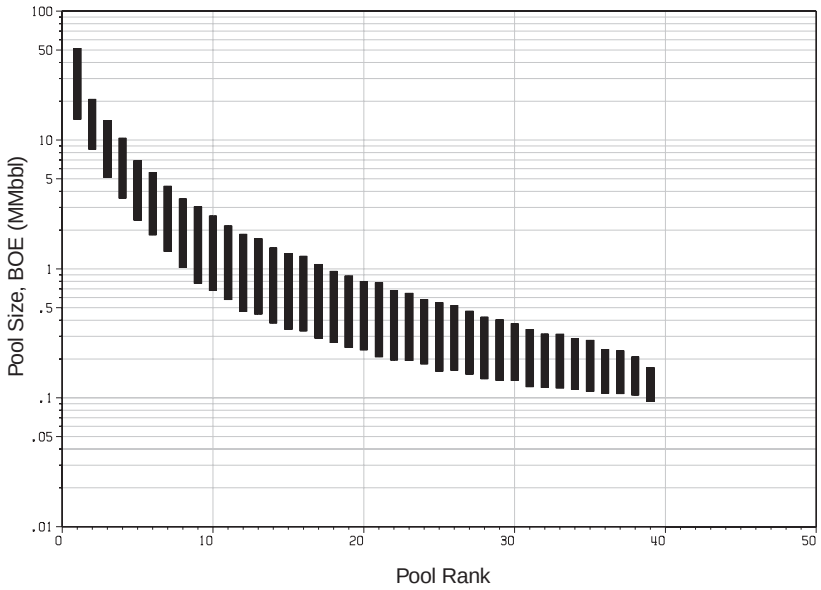

Figure 123. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Monterey Fractured play, Santa Rosa subarea of the Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

(mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 39 pools with sizes ranging from approximately 95 Mbbl to 50 MMbbl of combined oil-equivalent resources (fig. 123). The low, mean, and high estimates of resources in the play are listed in table 42.

LOWER MIOCENE SANDSTONE PLAYS

PLAY DEFINITION

The Lower Miocene Sandstone plays of the Santa Cruz basin and the Santa Rosa area are conceptual plays consisting of accumulations of oil and associated gas in lower Miocene clastic rocks. Because the plays are confined to the Santa Cruz basin proper and the Santa Rosa area proper, they have been individually assessed in each area.

The play exists over most of the Santa Cruz basin (fig. 117) where it encompasses an area of about 750 square miles. The depth to reservoir rocks in the play in this basin ranges from 3,000 to 6,500 feet below the seafloor.

The play also exists over most of the Santa Rosa area (fig. 117) where it encompasses an area of about 750 square miles. The depth to reservoir rocks in the play in this area ranges from 2,000 to 4,500 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The primary potential petroleum source rocks for these plays are Paleogene mudstones and shales (fig. 118). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks (Vedder, 1987). The geothermal gradient in this area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. Potential Paleogene source rocks are thin in the area, and the volume of generated oil and gas may therefore be small. Rocks of the Monterey Formation may be a secondary source of petroleum for reservoir rocks in the upper part of these plays.

Potential reservoir rocks in these plays are lower Miocene sandstones (fig. 118). Lower Miocene strata penetrated in the wells adjacent to the area

(OCS-P 0245 #1, OCS-P 0289 #1), and the wells on Dall, Tanner, and Cortes banks are described as porous and fine- to medium-grained sandstones with log-derived porosities ranging from 23 to 35 percent and with good permeability. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the Santa Cruz basin and the Santa Rosa area. Based on seismic mapping, rocks inferred to be of early Miocene age are areally extensive throughout the Santa Cruz basin and the Santa Rosa area; this stratigraphic unit has an average thickness of about 400 feet and a maximum thickness estimated to be 2,000 feet.

The dominant trap types in these plays are small to moderate anticlinal folds and associated reverse-fault traps.

EXPLORATION

Both of the exploratory wells adjacent to the Santa Cruz-Santa Rosa assessment area and most of the wells on Dall, Tanner, and Cortes banks penetrated rocks similar to those included in these plays; analog data from these wells have been used in the assessment of both plays.

No appreciable shows of hydrocarbons were encountered in any of the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in lower Miocene and other rocks in some of the wells.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in each play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in each play were estimated from seismic mapping. Conservatively reduced analog data from Vaqueros, Sespe, and Alegria producing zones in the offshore Santa Barbara-Ventura basin were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for both plays.

As a result of this assessment, the play in the Santa Cruz basin is estimated to contain 92 MMbbl of oil and 231 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 46 pools with sizes ranging from approximately 90 Mbbl to 105 MMbbl of combined oil-equivalent resources (fig. 124). The low, mean, and high estimates of resources in the play are listed in table 42.

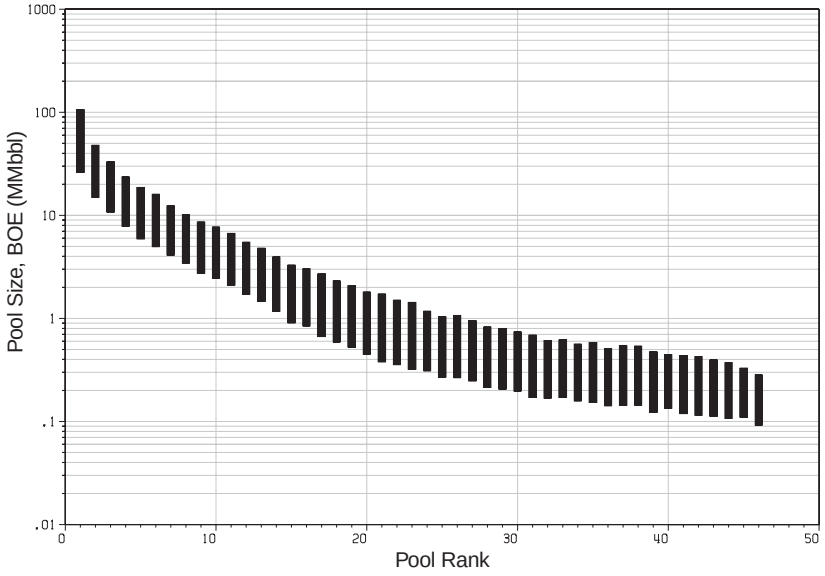

Figure 124. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Lower Miocene Sandstone play, Santa Cruz Basin subarea of the Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

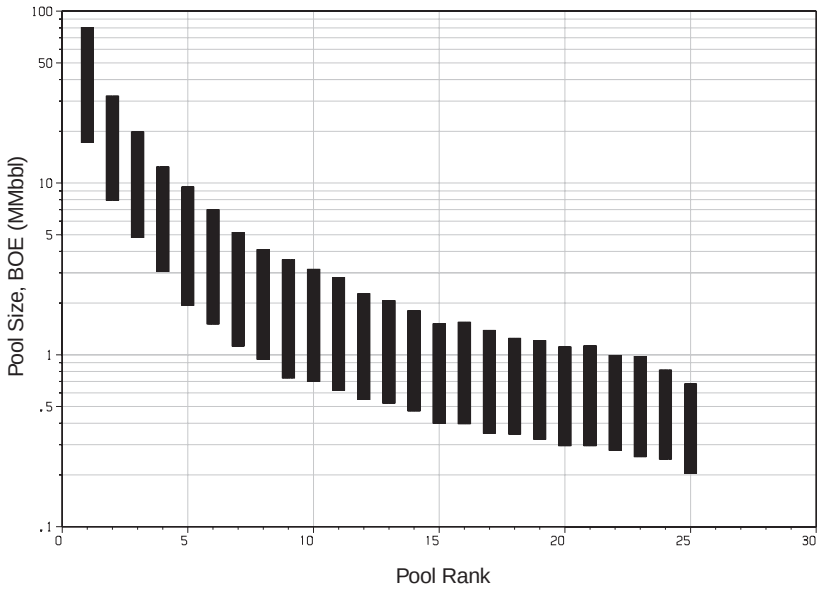

Figure 125. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Lower Miocene Sandstone play, Santa Rosa subarea of the Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

The play in the Santa Rosa area is estimated to contain 30 MMbbl of oil and 79 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 25 pools with sizes ranging from approximately 205 Mbbl to 80 MMbbl of combined oil-equivalent resources (fig. 125). The low, mean, and high estimates of resources in the play are listed in table 42.

PALEOGENE-CRETACEOUS SANDSTONE PLAY

PLAY DEFINITION

The Paleogene-Cretaceous Sandstone play of the Santa Cruz-Santa Rosa assessment area is a conceptual play consisting of accumulations of oil and associated gas in Upper Cretaceous and Paleogene clastic rocks. This play exists within and between the Santa Cruz basin and the Santa Rosa area (fig. 117) and encompasses an area of about 2,000 square miles. The depth to reservoir rocks in the play ranges from 6,500 to 9,000 feet below the seafloor in the Santa Cruz basin and from 4,000 to 8,000 feet below the seafloor in the Santa Rosa area.

PETROLEUM GEOLOGIC CHARACTERISTICS

The primary potential petroleum source rocks for this play are Paleogene mudstones and shales (fig. 118). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks; Upper Cretaceous shales containing 0.4 to 0.6 percent total organic carbon are not considered to be potential source rocks (Vedder, 1987). The geothermal gradient in this area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. However, potential source rocks are thin in the area, and the volume of generated oil and gas may therefore be small.

Potential reservoir rocks in this play are Paleogene and Cretaceous sandstones (fig. 118). Paleogene strata in the wells on Dall, Tanner, and Cortes banks are described as porous and fine- to coarse-grained sandstones; log-derived porosities range from 23 to 30 percent in Oligocene samples, from 10 to 25 percent in Eocene samples, and from 6 to 14 percent in Upper Cretaceous samples. The proportion of sandstone within the total section is

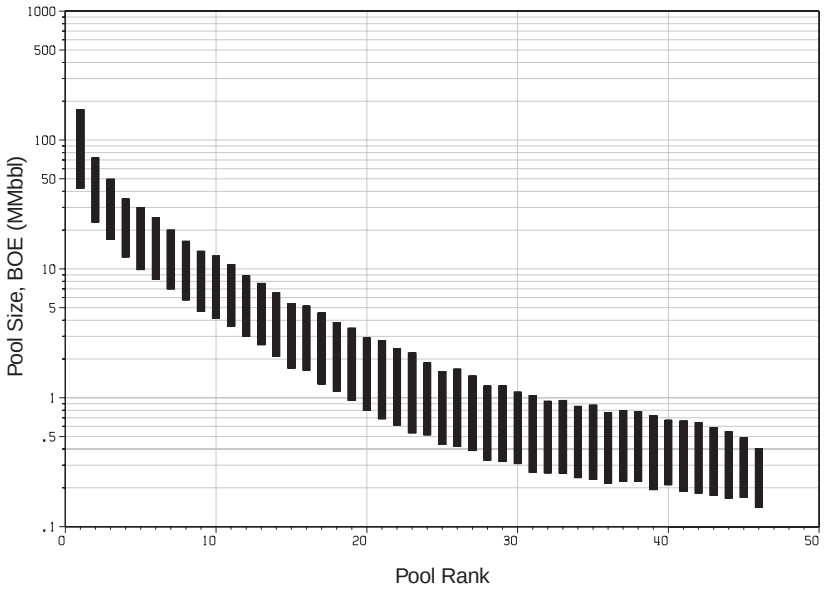

Figure 126. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Paleogene-Cretaceous Sandstone play, Santa Cruz-Santa Rosa assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

quite high; on average, sandstone composes approximately 50 percent of the total Paleogene section. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the Santa Cruz basin and the Santa Rosa assessment area. Based on seismic mapping and well correlations, rocks inferred to be of Paleogene and Cretaceous age are areally extensive throughout the Santa Cruz-Santa Rosa area; this stratigraphic unit has an average thickness of about 1,000 feet and a maximum thickness estimated to be 3,000 feet.

The dominant trap types in this play are small to moderate anticlinal folds and associated reverse-fault traps.

EXPLORATION

Both of the exploratory wells adjacent to the Santa Cruz-Santa Rosa assessment area and most of the wells on Dall, Tanner, and Cortes banks penetrated rocks similar to those included in this play; analog data from these wells have been used in the assessment of this play.

No appreciable shows of hydrocarbons were encountered in any of the wells. However, weak indications of gas were encountered in Paleogene-Cretaceous strata in the well south of Santa Rosa Island; other weak indications of hydrocarbons were encountered in Paleogene, Cretaceous, and other rocks in some of the wells on Dall, Tanner, and Cortes banks.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Analog data from Cretaceous, Eocene, and Oligocene producing zones in the Santa Barbara-Ventura, Los Angeles, and San Joaquin basins were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 92 MMbbl of oil and 207 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 46 pools with sizes ranging from approximately 140 Mbbl to 175 MMbbl of combined oil-equivalent resources (fig. 126). The low, mean, and high estimates of resources in the play are listed in table 42.

SAN NICOLAS BASIN

by Frank W. Victor

LOCATION

The San Nicolas Basin assessment area is located immediately southeast of San Nicolas Island in the Outer Borderland province (fig. 114). The basin is bounded on the east by the San Clemente ridge and on the west by the Santa Rosa-Cortes ridge; it extends from an unnamed east-west paleohigh between San Nicolas and Santa Barbara Islands (on the north) to Santo Tomas and Blake knolls (on the south) (fig. 127). It extends approximately 70 miles in length and from 10 to 30 miles in width and encompasses an area of approximately 1,300 square miles. The water depth within the basin ranges from 3,000 to 5,000 feet and averages 3,500 feet.

GEOLOGIC SETTING

The San Nicolas basin is an elongate, northwest-trending basin, which contains up to approximately 12,000 feet of Upper Cretaceous through

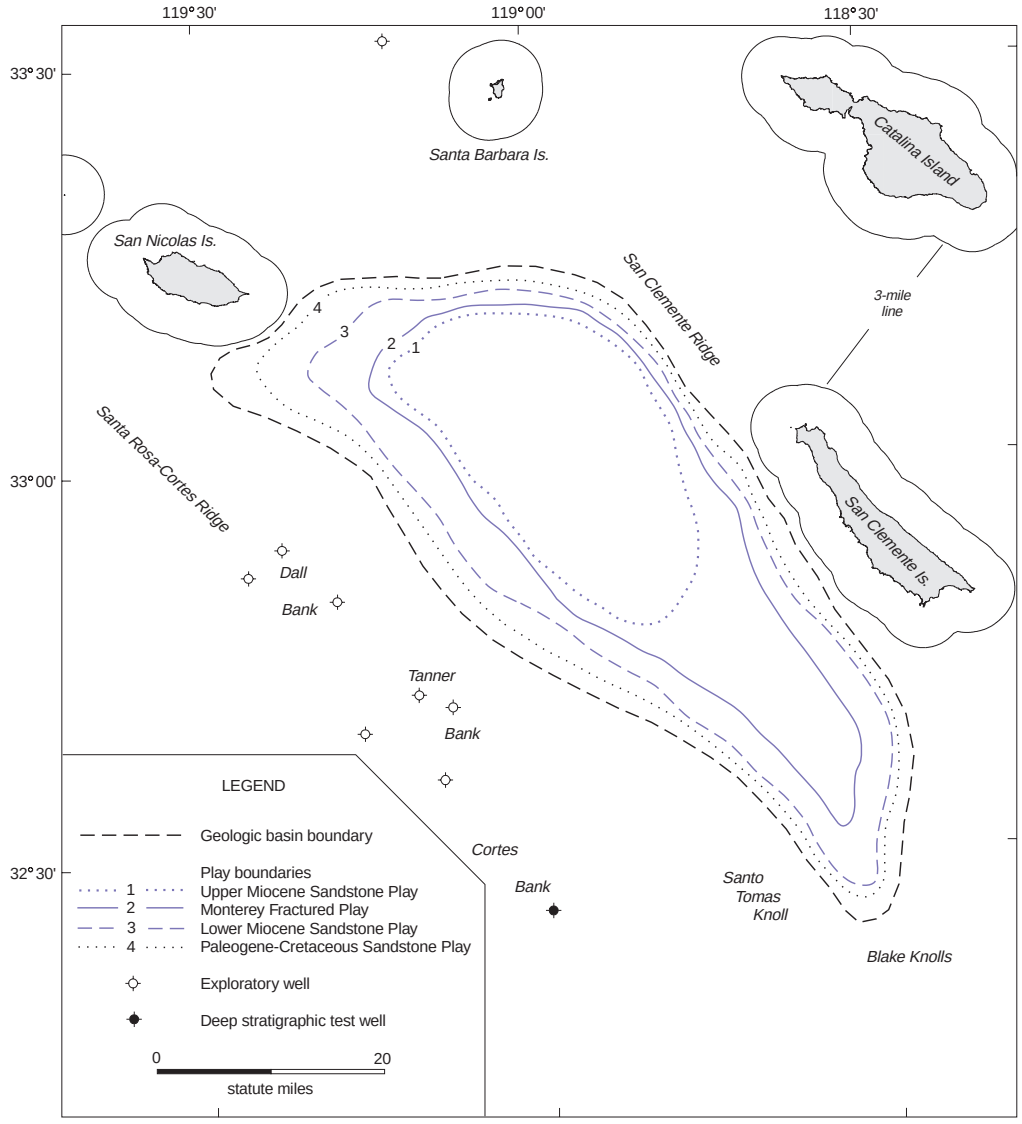

Figure 127. *Map of the San Nicolas Basin assessment area showing petroleum geologic plays and adjacent wells.*

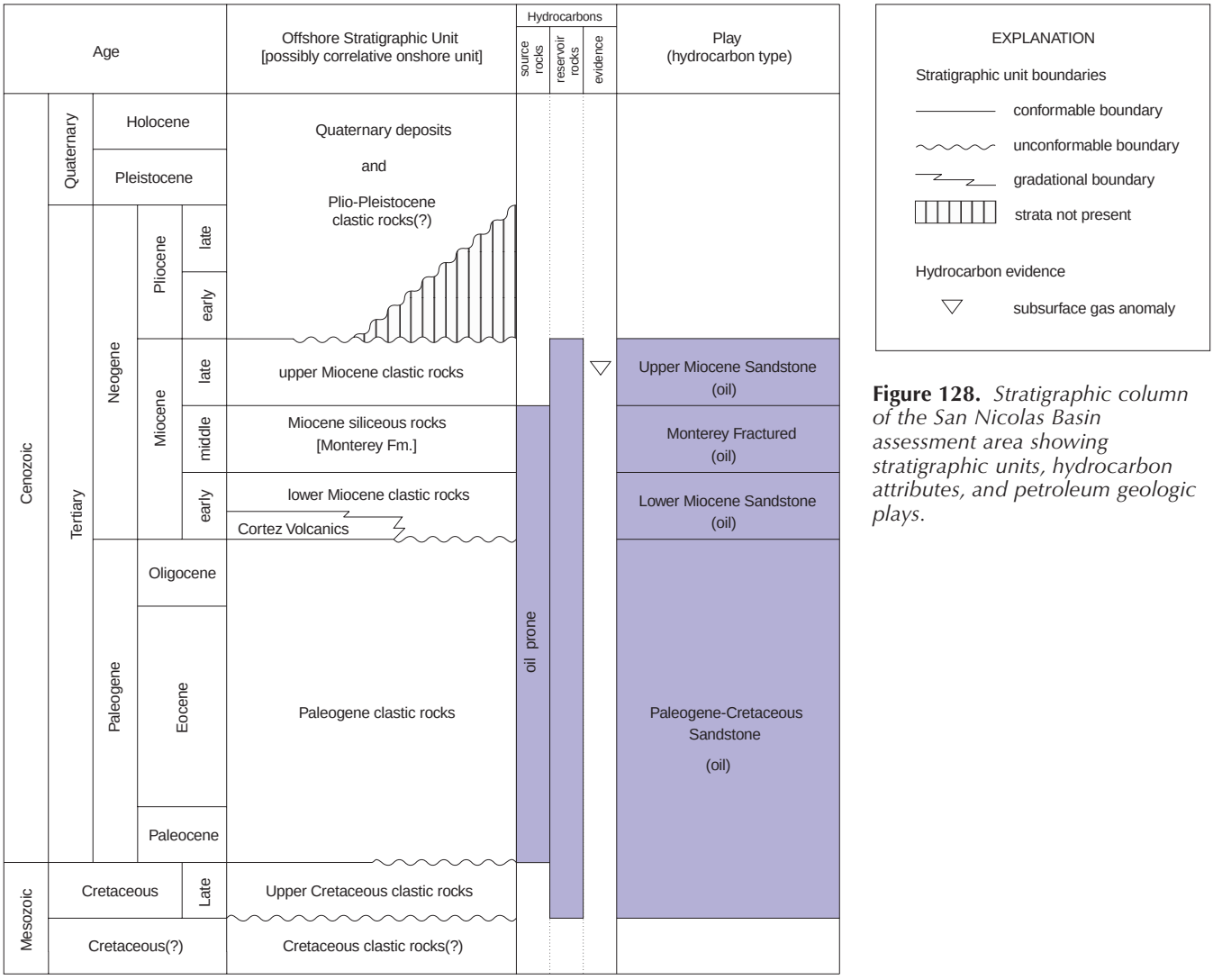

Figure 128. *Stratigraphic column of the San Nicolas Basin assessment area showing stratigraphic units, hydrocarbon attributes, and petroleum geologic plays.*

Quaternary strata[17] (fig. 128). The basin is asymmetrical, with the depocenter located in the northern third of the basin. Miocene compression, primarily from the west, has created a number of asymmetrical, reverse-fault-bounded anticlines in the eastern part of the basin. These structures are evident on seismic-reflection profiles and are numerous and large enough to trap significant quantities of oil and gas.

EXPLORATION

No exploratory wells have been drilled within the San Nicolas basin; however, a number of high-quality seismic-reflection surveys have been recorded. Eight wells were drilled immediately west of the basin on the southern end of the Santa Rosa-Cortes ridge. These include a deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank and seven exploratory oil and gas wells on Dall and Tanner banks.

These wells penetrated lower Miocene, Paleogene, and Cretaceous strata. Most middle Miocene and younger strata have been eroded from the uplifted banks on which the wells were drilled; however, middle Miocene and younger strata are present and relatively thick within the San Nicolas basin. The approximate geologic age of these undrilled stratigraphic units is based on seismic-stratigraphic extrapolation of older strata from the wells and on

[17] Descriptions of the age and lithology of stratigraphic units in the San Nicolas Basin assessment area are based on inference (rather than direct evidence) because no wells have been drilled within the area. Individual stratigraphic units are inferred to exist based on seismic-stratigraphic extrapolation of units that have been penetrated in wells on the Santa Rosa-Cortes ridge; analog data from these wells have been used in the assessment of plays in the San Nicolas Basin assessment area.

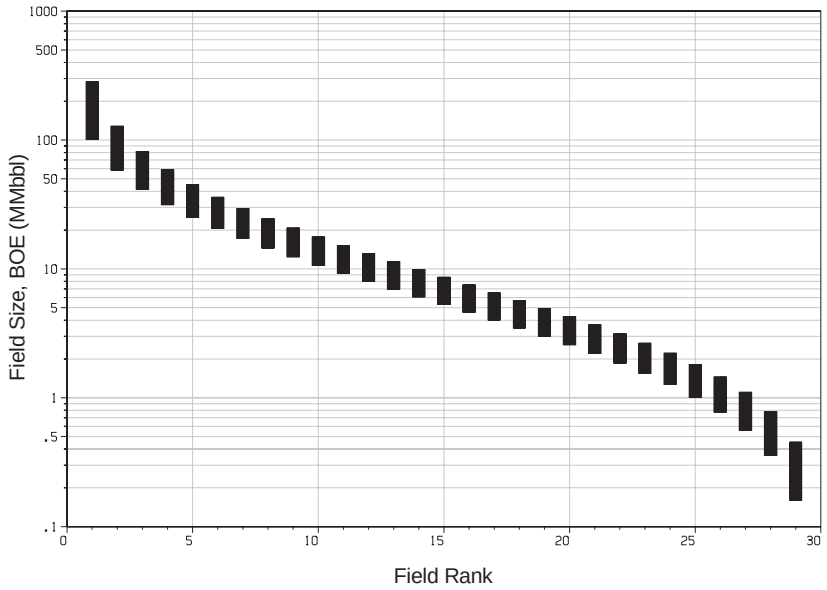

Figure 129. *Field-size rank plot of estimated undiscovered conventionally recoverable resources of the San Nicolas Basin assessment area. Sizes of undiscovered fields are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile value of a probability distribution, respectively.*

the absence of significant unconformities within middle Miocene and younger strata in the basin.

No appreciable shows of oil or gas were encountered in the adjacent wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in some of the wells. Possible gas-related amplitude anomalies within the upper Miocene stratigraphic section are present on seismic profiles.

Plays

Four petroleum geologic plays have been defined in the San Nicolas basin (fig. 128). The plays were defined on the basis of reservoir rock stratigraphy. The plays (and corresponding reservoir rocks) consist of the Upper Miocene Sandstone play (clastic rocks), the Monterey Fractured play (fractured rocks), the Lower Miocene Sandstone play (clastic rocks), and the Paleogene-Cretaceous Sandstone play (clastic rocks).

All of the plays in the basin are considered to be conceptual plays based on the absence of directly detected hydrocarbons within the play areas. This is presumed to be a consequence of the location and limited number of the wells rather than a lack of geological conditions conducive to hydrocarbon accumulation.

Resource Estimates

Undiscovered Conventionally Recoverable Resources

Play-specific estimates of undiscovered conventionally recoverable resources have been developed using the subjective assessment method, and these estimates have been statistically aggregated to estimate the total volume of resources in the basin. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the San Nicolas basin is estimated to be 545 MMbbl of oil and 909 Bcf of associated gas (mean estimates). This volume may exist in 29 fields with sizes ranging from approximately 160 Mbbl to 285 MMbbl of combined oil-equivalent resources (fig. 129). The low, mean, and high estimates of resources in the assessment area are listed in table 44 and illustrated in figure 130.

Undiscovered Economically Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the assessment area that may be economically recoverable under various economic scenarios have been developed using the economic assessment method. Select data used to develop the resource estimates are shown in appendix D.

As a result of this assessment, 55 MMbbl of oil and 91 Bcf of associated gas are estimated to be economically recoverable from the San Nicolas Basin assessment area under economic conditions existing as of this assessment (i.e., the $18-per-barrel economic scenario) (table 45). Larger volumes of resources are expected to be economically recoverable under increasingly favorable economic conditions (fig. 131).

Total Resource Endowment

No accumulations of resources have been discovered in the assessment area. Therefore, the aforementioned estimates of undiscovered conventionally recoverable resources compose the estimated total resource endowment of the area.

Table 44. *Estimates of undiscovered conventionally recoverable oil and gas resources in the San Nicolas Basin assessment area as of January 1, 1995, by play. All estimates are risked values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.*

Play	Oil (MMbbl)			Gas (Bcf)			BOE (MMbbl)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Upper Miocene Sandstone	0	73	269	0	38	149	0	80	295
Monterey Fractured	0	202	533	0	226	581	0	243	629
Lower Miocene Sandstone	0	159	570	0	364	1,319	0	224	818
Paleogene-Cretaceous Sandstone	0	110	416	0	281	1,241	0	161	628
Total Assessment Area	*0*	*545*	*1,176*	*0*	*909*	*2,417*	*0*	*707*	*1,576*

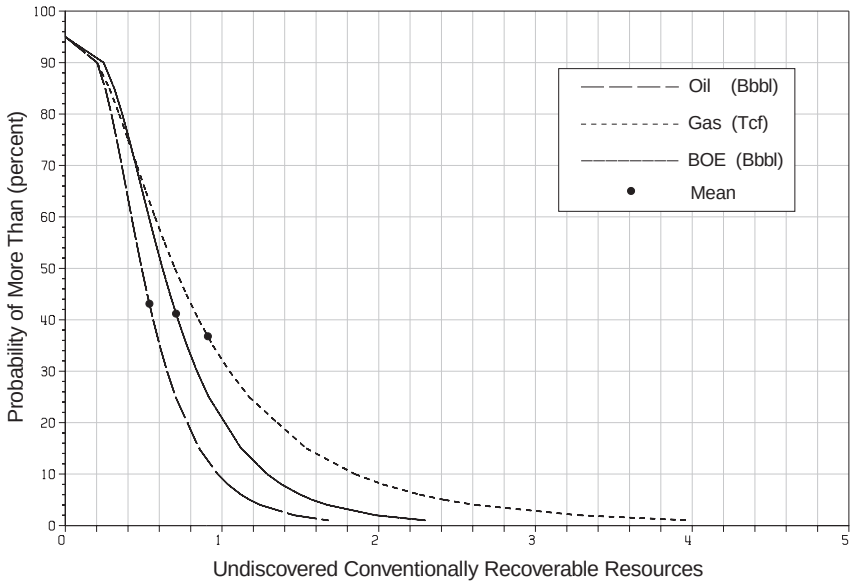

Figure 130. *Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the San Nicolas Basin assessment area.*

Table 45. *Estimates of undiscovered economically recoverable oil and gas resources in the San Nicolas Basin assessment area as of January 1, 1995, by economic scenario. All estimates are risked mean values. The $18-per-barrel scenario is based on prices of $18 per bbl of oil and $2.11 per Mcf of gas; the $25-per-barrel scenario is based on prices of $25 per bbl of oil and $2.94 per Mcf of gas; the $50-per-barrel scenario is based on prices of $50 per barrel of oil and $5.87 per Mcf of gas.*

Economic Scenario	Oil (MMbbl)	Gas (Bcf)	BOE (MMbbl)
$18 per barrel	55	91	71
$25 per barrel	204	339	264
$50 per barrel	404	673	524

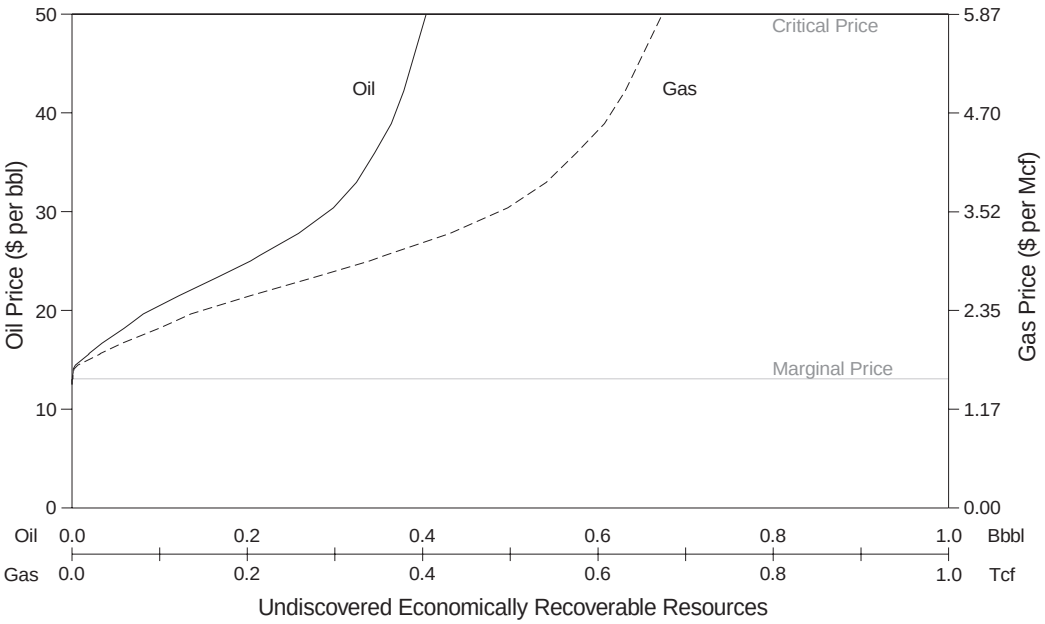

Figure 131. *Price-supply plot of estimated undiscovered economically recoverable resources of the San Nicolas Basin assessment area.*

Upper Miocene Sandstone Play

Play Definition

The Upper Miocene Sandstone play of the San Nicolas Basin assessment area is a conceptual play consisting of accumulations of oil and associated gas in upper Miocene sandstones. The play exists in the north-central part of the basin, where it encompasses an area of approximately 500 square miles (fig. 127). The depth to reservoir rocks in the play ranges from 1,000 to 5,000 feet below the seafloor.

Petroleum Geologic Characteristics

Potential petroleum source rocks for this play are middle Miocene shales of the Monterey Formation (fig. 128). The type and amount of organic matter within Monterey rocks of the San Nicolas basin are unknown; however, Monterey rocks in other California coastal basins are rich in organic matter, and similar rocks are presumed to exist in the San Nicolas basin. The geothermal gradient and the depth at which thermal maturation may have occurred in the San Nicolas basin are also unknown. The Monterey is buried no more than 6,000 feet and may not have been buried sufficiently to permit petroleum generation. However, the existence of "diagenetic reflectors" on seismic profiles suggests that temperatures conducive to silica diagenesis and possibly petroleum generation may have been attained in Monterey rocks. Due to the relatively shallow depths of the potential reservoir rocks, the oil in this play is predicted to be of low (less than 25 °API) gravity.

Potential reservoir rocks in this play include upper Miocene turbidite sandstones (fig. 128). Seismic profiles suggest that the upper Miocene section is thin in the San Nicolas basin; the average thickness of the unit is about 2,000 feet, and the maximum thickness is estimated to be about 4,000 feet. Potential reservoir sandstones should have good to excellent porosity and permeability based on burial depth and depositional history. However, based on the presence of relatively thin sections of lower Miocene strata in the wells adjacent to the basin, thin pay zones are expected in this play. Strata penetrated by the wells included fine- to medium-grained sandstones with log-derived porosities of 23 to 32 percent and good permeability.

The dominant trap type in this play is the relatively low-relief, simple anticlinal structure. The structural trend of prospects in the basin is northwest-southeast. However, there are very few structural prospects within the play area due to the lack of post-Miocene tectonic activity and absence of significant structural relief.

EXPLORATION

None of the exploratory wells adjacent to the San Nicolas basin penetrated rocks similar to those included in this play due to erosion of middle Miocene and younger strata from the uplifted banks on which the wells were drilled. Upper Miocene strata are inferred to exist in the basin based on seismic-stratigraphic extrapolation of older strata from these wells. Possible gas-related amplitude anomalies within the upper Miocene stratigraphic section are present on seismic profiles.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Conservatively reduced analog data from Puente producing zones in the onshore Los Angeles basin were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 73 MMbbl of oil and 38 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 34 pools with sizes ranging from approximately 210 Mbbl to 90 MMbbl of combined oil-equivalent resources (fig. 132). The low, mean, and high estimates of resources in the play are listed in table 44.

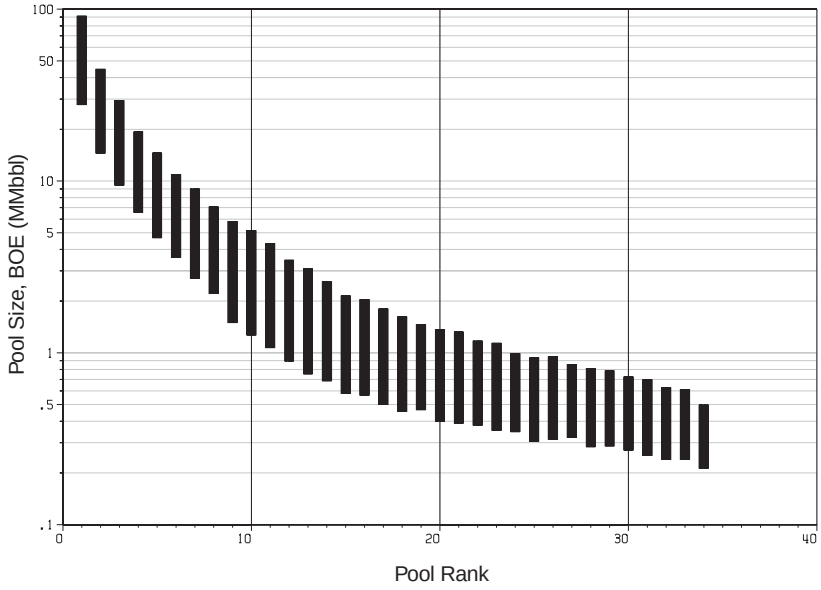

Figure 132. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Upper Miocene Sandstone play, San Nicolas Basin assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

MONTEREY FRACTURED PLAY

PLAY DEFINITION

The Monterey Fractured play of the San Nicolas Basin assessment area is a conceptual play consisting of accumulations of oil and associated gas in middle Miocene fractured rocks of the Monterey Formation. The play exists over most of the basin where it encompasses an area of about 700 square miles (fig. 127). The depth to reservoir rocks in the play ranges from 3,600 to 6,500 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The Monterey Formation is considered to be both petroleum source rock and reservoir rock for this play (fig. 128) by analogy with Monterey rocks in the offshore Santa Barbara-Ventura and Santa Maria basins and the onshore San Joaquin basin. The type and amount of organic matter within Monterey rocks of the San Nicolas basin are unknown; however, Monterey rocks in other California coastal basins are rich in organic matter, and similar rocks

are presumed to exist in the San Nicolas basin. The geothermal gradient and the depth at which thermal maturation may have occurred in the San Nicolas basin are also unknown. The Monterey is buried no more than 6,000 feet and may not have been buried sufficiently to permit petroleum generation. However, the existence of "diagenetic reflectors" on seismic profiles suggests that temperatures conducive to silica diagenesis and possibly petroleum generation may have been attained in Monterey rocks. Due to the moderate depths of the potential reservoir rocks, the oil in this play is predicted to be of moderate (less than 30 °API) gravity.

Potential reservoir rocks in this play include middle Miocene fractured siliceous and calcareous shales and cherts and perhaps some basal clastic rocks of the Monterey Formation (fig. 128). Seismic profiles suggest that the Monterey section is thin in the basin; the thickness of these rocks is estimated to range from 500 to 1,000 feet. Diagenetic alteration, compression, and folding may have enhanced fracturing of the shales and cherts. In general, Monterey strata in the San Nicolas basin are expected to have reservoir characteristics similar to those in the offshore Santa Barbara-Ventura and Santa Maria basins.

The dominant trap type in this play is expected to be the anticline.

Exploration

None of the exploratory wells adjacent to the San Nicolas basin penetrated rocks similar to those included in this play due to erosion of middle Miocene and younger strata from the uplifted banks on which the wells were drilled. Middle Miocene strata presumably equivalent to the Monterey Formation are inferred to exist in the basin based on seismic-stratigraphic extrapolation of older strata from these wells.

Resource Estimates

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The volume and number of prospects in the play were estimated from seismic mapping. Conservatively reduced analog data from Monterey producing zones in the offshore Santa Barbara-Ventura and Santa Maria basins were used to estimate the oil recovery factor and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 202 MMbbl of oil and 226 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 50 pools with sizes ranging from approximately 40 Mbbl to 260 MMbbl of combined oil-equivalent resources (fig. 133). The low, mean, and high estimates of resources in the play are listed in table 44.

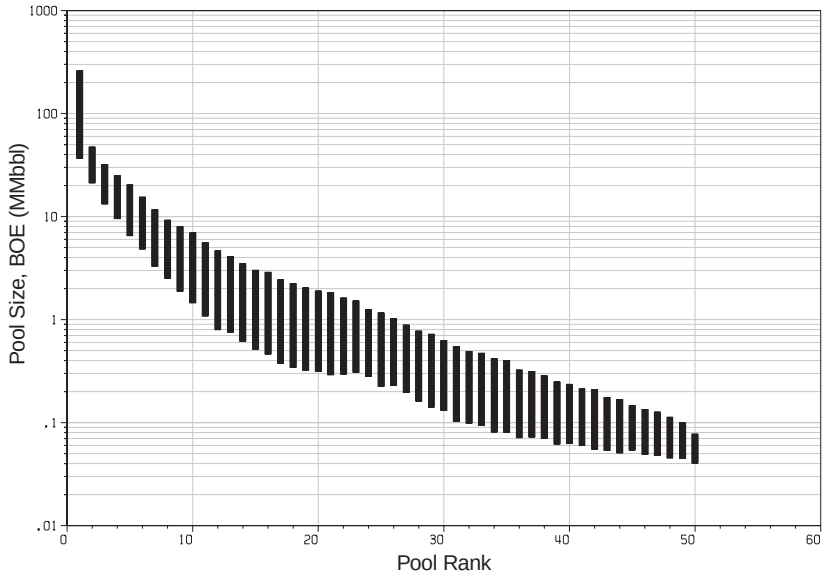

Figure 133. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Monterey Fractured play, San Nicolas Basin assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

LOWER MIOCENE SANDSTONE PLAY

PLAY DEFINITION

The Lower Miocene Sandstone play of the San Nicolas Basin assessment area is a conceptual play consisting of accumulations of oil and associated gas in lower Miocene sandstones. The play exists over most of the basin where it encompasses an area of about 900 square miles (fig. 127). The depth to reservoir rocks in the play ranges from 4,000 to 8,500 feet, and averages 7,500 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The primary potential petroleum source rocks for this play are Paleogene and lower Miocene mudstones and shales (fig. 128). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks (Vedder, 1987). Geochemical analysis of lower Miocene dart samples yielded an average total organic carbon content of 3.2 weight percent (Vedder, 1987). The geothermal gradient in this area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. However, potential source rocks are thin in the basin, and the volume of generated oil and gas may therefore be small. Rocks of the Monterey Formation may be a secondary source of petroleum for reservoir rocks in the upper part of this play.

Potential reservoir rocks in this play are lower Miocene sandstones (fig. 128). Lower Miocene strata penetrated in the wells adjacent to the basin are described as porous and fine- to medium-grained sandstones with log-derived porosities of 23 to 32 percent and with good permeability. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the San Nicolas basin. Based on seismic mapping, rocks inferred to be of early Miocene age are areally extensive throughout the San Nicolas basin; this stratigraphic unit has an average thickness of about 500 feet and a maximum thickness estimated to be 2,000 feet.

The dominant trap types in this play are small to large anticlinal folds and associated reverse-fault traps.

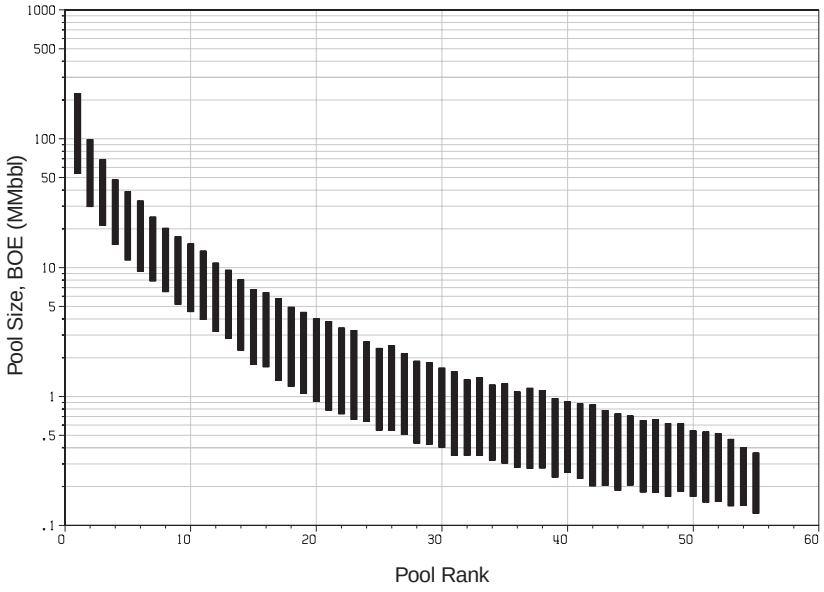

Figure 134. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Lower Miocene Sandstone play, San Nicolas Basin assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

Exploration

Most of the exploratory wells adjacent to the San Nicolas basin penetrated rocks similar to those included in this play. No appreciable shows of hydrocarbons were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in lower Miocene and other rocks in some of the wells.

Resource Estimates

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Conservatively reduced analog data from Vaqueros, Sespe, and Alegria producing zones in the offshore Santa Barbara-Ventura basin were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 159 MMbbl of oil and 364 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 55 pools with sizes ranging from approximately 125 Mbbl to 225 MMbbl of combined oil-equivalent resources (fig. 134). The low, mean, and high estimates of resources in the play are listed in table 44.

Paleogene-Cretaceous Sandstone Play

Play Definition

The Paleogene-Cretaceous Sandstone play of the San Nicolas Basin assessment area is a conceptual play consisting of accumulations of oil and associated gas in Upper Cretaceous and Paleogene sandstones. The play exists over most of the basin where it encompasses an area of about 1,100 square miles (fig. 127). The depth to reservoir rocks in the play ranges from 8,000 to 11,000 feet and averages 9,000 feet below the seafloor.

Petroleum Geologic Characteristics

The primary potential petroleum source rocks for this play are Paleogene mudstones and shales (fig. 128). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks; Upper Cretaceous shales containing 0.4 to 0.6 percent total organic carbon are not considered to be potential source rocks (Vedder, 1987). The geothermal gradient in this area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. However, potential source rocks are thin in the area, and the volume of generated oil and gas may therefore be small.

Potential reservoir rocks in this play are Paleogene and Cretaceous sandstones (fig. 128). Paleogene strata in the wells adjacent to the basin are described as porous and fine- to coarse-grained sandstones; log-derived porosities range from 23 to 30 percent in Oligocene samples, from 10 to 25 percent in Eocene samples, and from 6 to 14 percent in Upper Cretaceous samples. The proportion of sandstone within the total section is quite high; on average, sandstone composes approximately 50 percent of the total Paleogene section. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the San Nicolas basin. Based on seismic mapping and well correlations, rocks inferred to be of Paleogene and Cretaceous age are areally extensive throughout the San Nicolas basin; this stratigraphic unit has an average thickness of about 1,500 feet and a maximum thickness estimated to be 3,000 feet.

The dominant trap types in this play are small to large anticlinal folds and associated reverse-fault traps.

Exploration

All of the exploratory wells adjacent to the San Nicolas basin penetrated Paleogene rocks similar to those included in this play and most of the wells penetrated Cretaceous rocks. No appreciable shows of hydrocarbons were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in Paleogene, Cretaceous, and

other rocks in some of the wells.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Analog data from Cretaceous, Eocene, and Oligocene producing zones in the Santa Barbara-Ventura, Los Angeles, and San Joaquin basins were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 110 MMbbl of oil and 281 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 45 pools with sizes ranging from approximately 175 Mbbl to 190 MMbbl of combined oil-equivalent resources (fig. 135). The low, mean, and high estimates of resources in the play are listed in table 44.

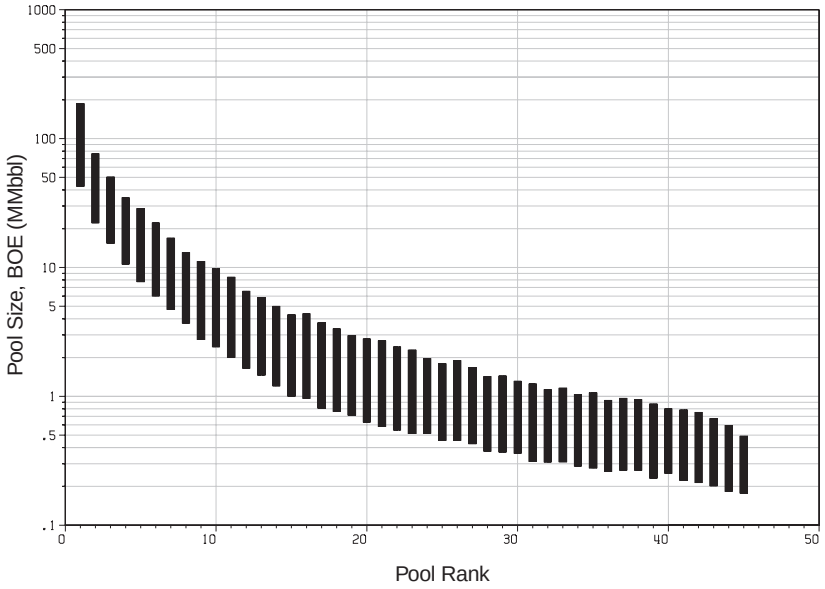

Figure 135. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Paleogene-Cretaceous Sandstone play, San Nicolas Basin assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

CORTES-VELERO-LONG AREA

by Frank W. Victor

LOCATION

The Cortes-Velero-Long assessment area is located in the southern part of the Outer Borderland province (fig. 114). This northwest-trending assessment area is approximately bounded by the Santo Tomas and Blake knolls to the east, the Patton escarpment to the west, the Northeast and Tanner banks to the north, and the U.S.-Mexico maritime boundary to the south (fig. 136). It is approximately 95 miles long, from 30 to 60 miles wide, and encompasses an area of approximately 4,800 square miles. The water depth within the area ranges from 4,500 to 6,000 feet.

This composite assessment area comprises the U.S. Federal portion of four geologic subareas: the West Cortes, East Cortes, Velero, and Long basins. These subareas have been combined as a single assessment area due to the nearly continuous extent of Paleogene strata and lack of definitive basin boundaries. The southern part of the Velero basin extends beyond the U.S.-Mexico maritime boundary; it is not included in the assessment area and has not been assessed.

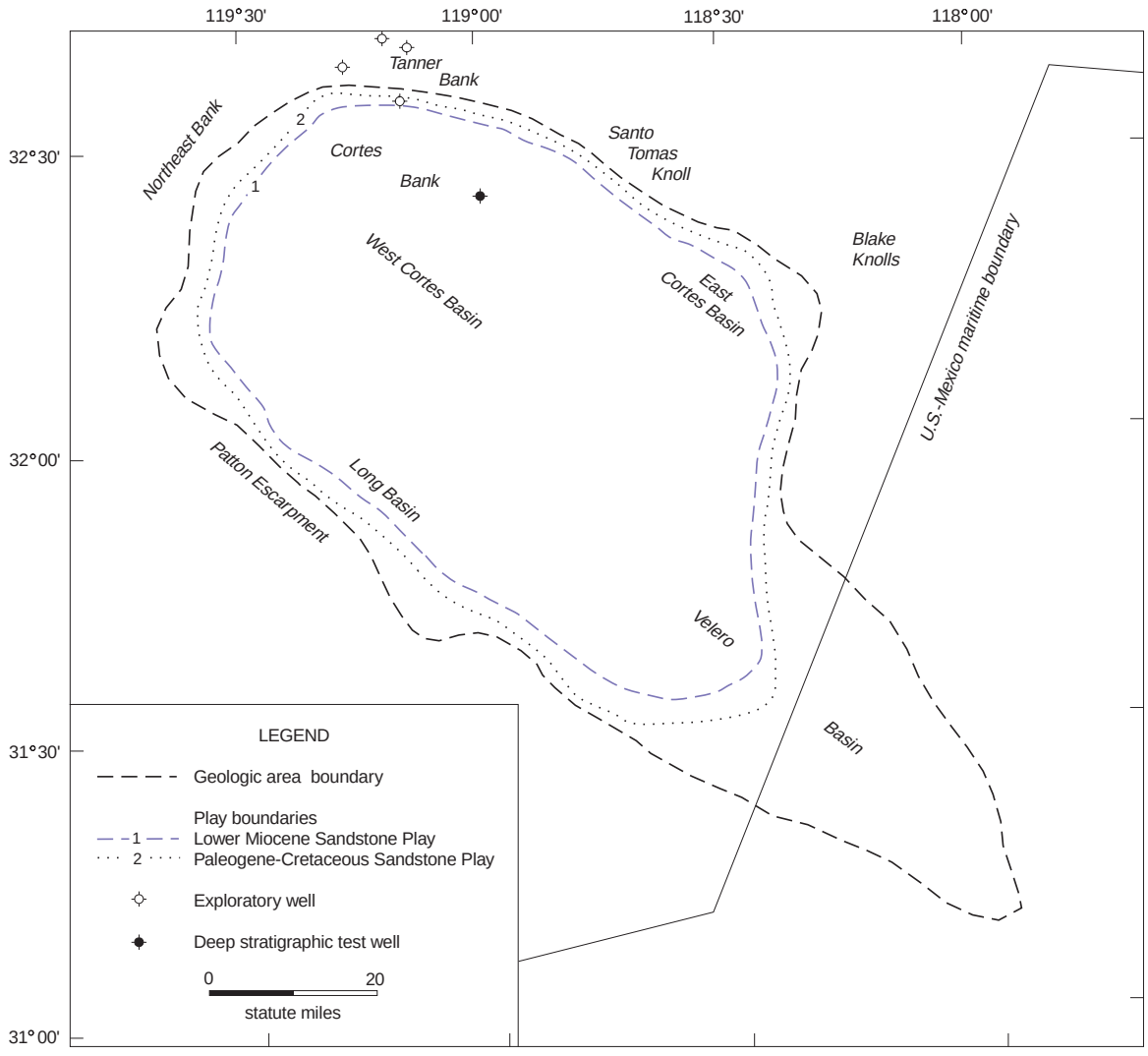

Figure 136. *Map of the Cortes-Velero-Long assessment area showing petroleum geologic plays and wells.*

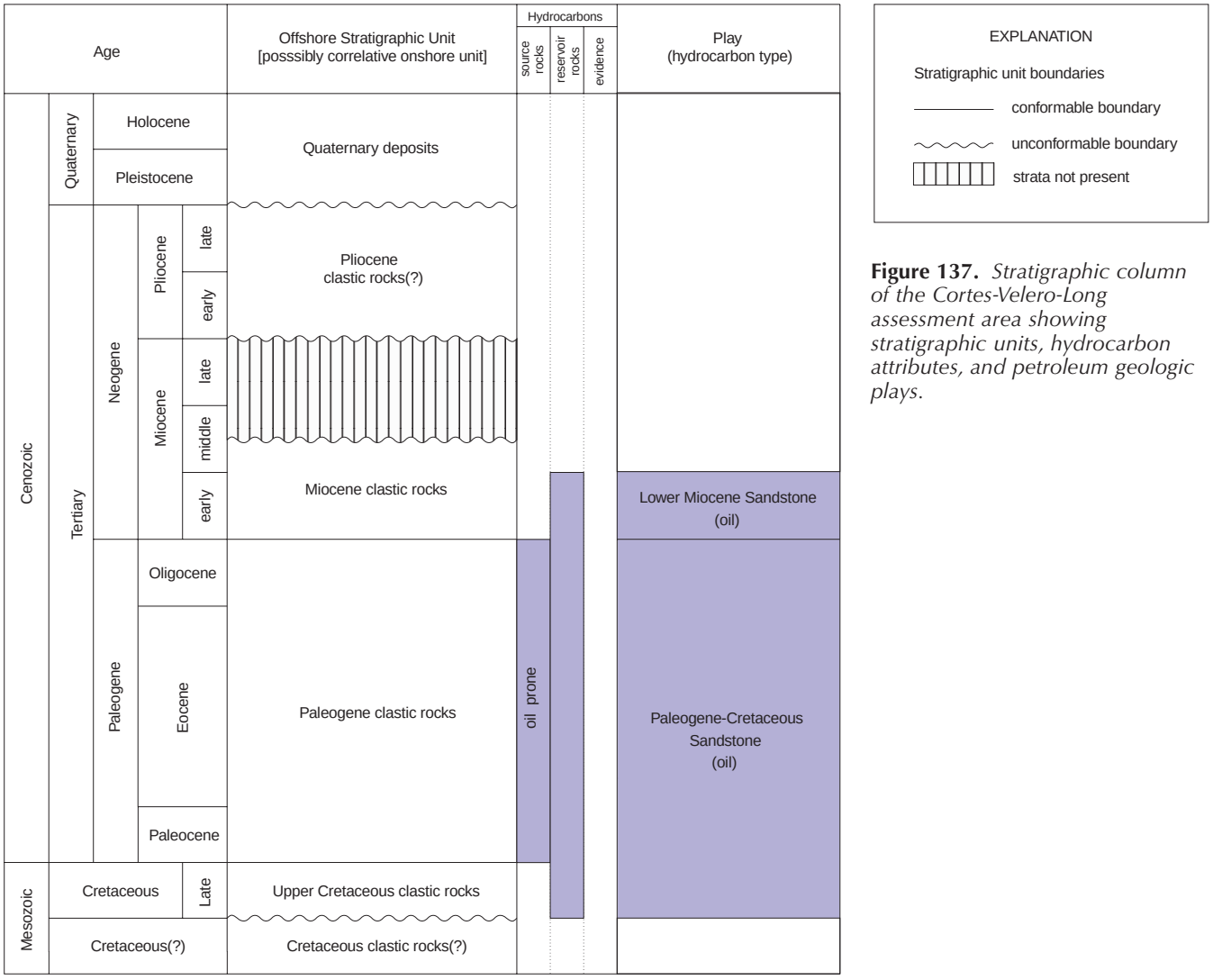

Figure 137. *Stratigraphic column of the Cortes-Velero-Long assessment area showing stratigraphic units, hydrocarbon attributes, and petroleum geologic plays.*

GEOLOGIC SETTING

The basins within the Cortes-Velero-Long assessment area are northwest-trending basins, which contain up to 7,000 feet of Upper Cretaceous through Miocene marine clastic rocks[18] (fig. 137). This remote area of the continental borderland has lacked a source of a significant volume of clastic sediment since the middle Miocene resulting in the deposition of thin sequences of predominantly biogenic (rather than terrestrial) sediment and basins that contain little or no middle Miocene and younger strata.

This part of the continental borderland has been tectonically dominated by extension and strike-slip faulting, which created a number of very broad, low-relief, normal-fault-bounded traps throughout the area. These structures are evident on seismic profiles and are numerous and large enough to trap significant quantities of oil and gas.

EXPLORATION

No exploratory wells have been drilled within the basinal areas of the Cortes-Velero-Long assessment area; however, a number of high-quality seismic-reflection surveys have been recorded. Eight wells were drilled on the southern end of the Santa Rosa-Cortes ridge. These include a deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank (in the northern part of the assessment area) and seven exploratory oil and gas wells on Dall and Tanner

[18] Descriptions of the age and lithology of stratigraphic units in the Cortes-Velero-Long assessment area are based on inference (rather than direct evidence) because no wells have been drilled within the area. Individual stratigraphic units are inferred to exist based on seismic-stratigraphic extrapolation of units that have been penetrated in wells on the Santa Rosa-Cortes ridge; analog data from these wells have been used in the assessment of plays in the Cortes-Velero-Long assessment area.

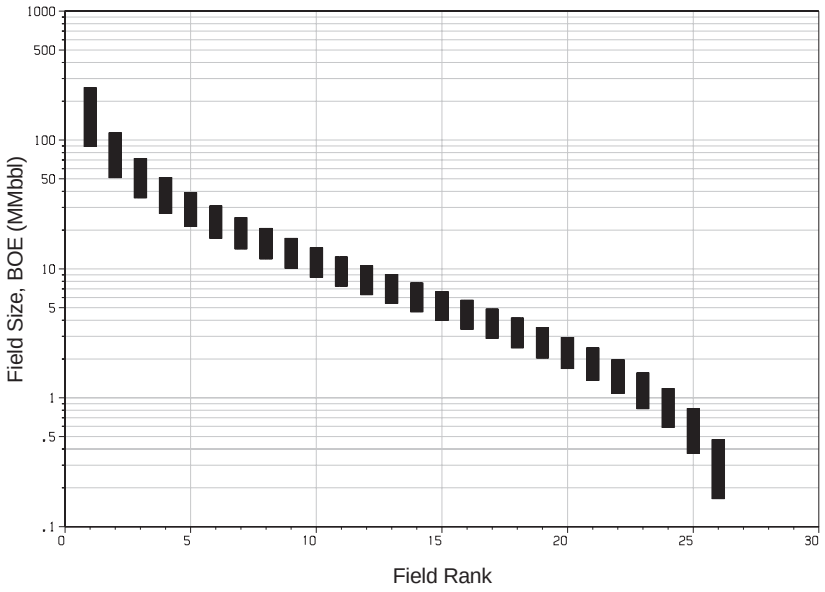

Figure 138. *Field-size rank plot of estimated undiscovered conventionally recoverable resources of the Cortes-Velero-Long assessment area. Sizes of undiscovered fields are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile value of a probability distribution, respectively.*

banks (one of which lies on the extreme northern flank of the assessment area).

These wells penetrated lower Miocene, Paleogene, and Cretaceous strata. Most middle Miocene and younger strata have been eroded from the uplifted banks on which the wells were drilled.

No appreciable shows of oil or gas were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in some of the wells.

PLAYS

Two petroleum geologic plays have been defined in the Cortes-Velero-Long assessment area. The plays were defined on the basis of reservoir rock stratigraphy. The plays (and corresponding reservoir rocks) consist of the Lower Miocene Sandstone play (clastic rocks) and the Paleogene-Cretaceous Sandstone play (clastic rocks).

Both of the plays in the area are considered to be conceptual plays based on the absence of directly detected hydrocarbons within the play areas. This is presumed to be a consequence of the location and limited number of the wells rather than a lack of geological conditions conducive to hydrocarbon accumulation.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Play-specific estimates of undiscovered conventionally recoverable resources have been developed using the subjective assessment method, and these estimates have been statistically aggregated to estimate the total volume of resources in the assessment area. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the Cortes-Velero-Long assessment area is estimated to be 412 MMbbl of oil and 1.10 Tcf of associated gas (mean estimates). This volume may exist in 26 fields with sizes ranging from approximately 165 Mbbl to 255 MMbbl of combined oil-equivalent resources (fig. 138). The low, mean, and high estimates of resources in the assessment area are listed in table 46 and illustrated in figure 139.

Undiscovered Economically Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the assessment area that may be economically recoverable under various economic scenarios have been developed using the economic assessment method. Select data used to develop the resource estimates are shown in appendix D.

As a result of this assessment, no oil and gas resources are estimated to be economically recoverable from the Cortes-Velero-Long assessment area under economic conditions existing as of this assessment (i.e., the $18-per-barrel economic scenario) (table 47). However, small to moderate volumes of resources are expected to be economically recoverable under increasingly favorable economic conditions (fig. 140).

Total Resource Endowment

No accumulations of resources have been discovered in the assessment area. Therefore, the aforementioned estimates of undiscovered conventionally recoverable resources compose the estimated total resource endowment of the area.

Table 46. *Estimates of undiscovered conventionally recoverable oil and gas resources in the Cortes-Velero-Long assessment area as of January 1, 1995, by play. All estimates are risked values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.*

Play	Oil (MMbbl)			Gas (Bcf)			BOE (MMbbl)		
	Low	Mean	High	Low	Mean	High	Low	Mean	High
Lower Miocene Sandstone	0	242	792	0	659	2,583	0	360	1,265
Paleogene-Cretaceous Sandstone	0	169	693	0	442	2,168	0	248	1,111
Total Assessment Area	*0*	*412*	*1,202*	*0*	*1,101*	*3,493*	*0*	*607*	*1,797*

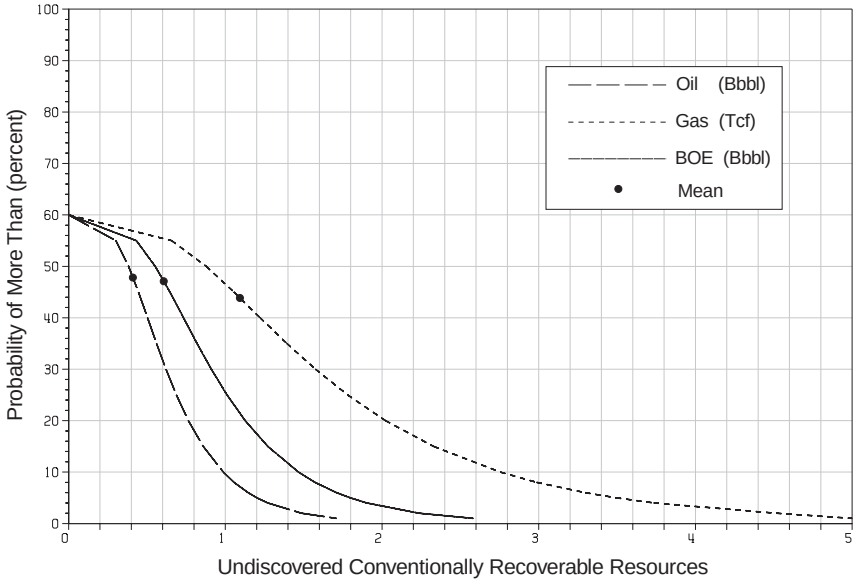

Figure 139. *Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the Cortes-Velero-Long assessment area.*

Table 47. *Estimates of undiscovered economically recoverable oil and gas resources in the Cortes-Velero-Long assessment area as of January 1, 1995, by economic scenario. All estimates are risked mean values. The $18-per-barrel scenario is based on prices of $18 per bbl of oil and $2.11 per Mcf of gas; the $25-per-barrel scenario is based on prices of $25 per bbl of oil and $2.94 per Mcf of gas; the $50-per-barrel scenario is based on prices of $50 per barrel of oil and $5.87 per Mcf of gas.*

Economic Scenario	Oil (MMbbl)	Gas (Bcf)	BOE (MMbbl)
$18 per barrel	0	0	0
$25 per barrel	2	6	3
$50 per barrel	213	568	314

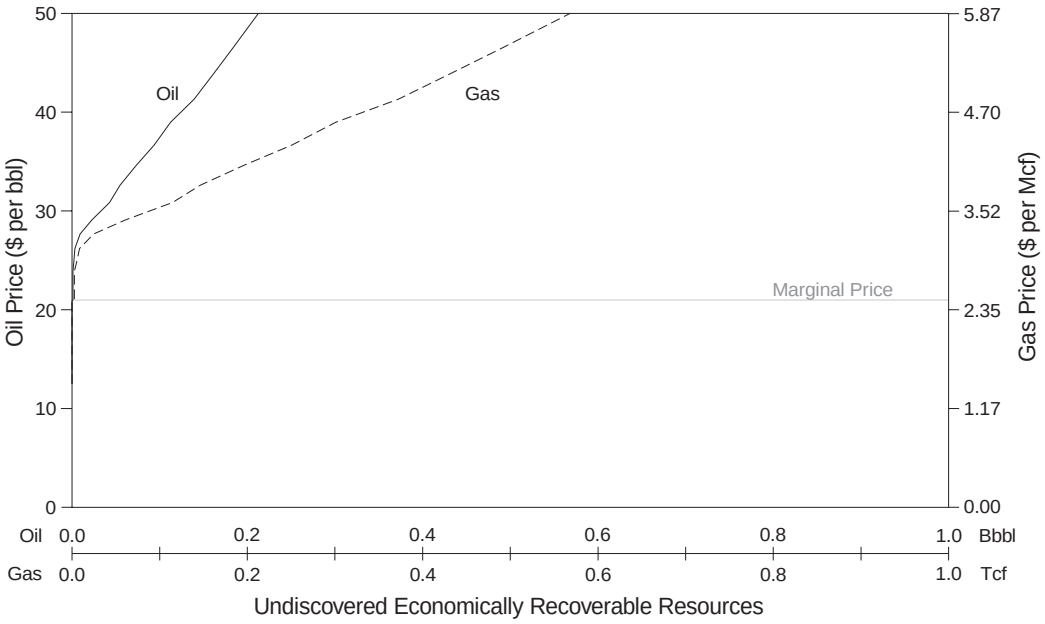

Figure 140. *Price-supply plot of estimated undiscovered economically recoverable resources of the Cortes-Velero-Long assessment area.*

LOWER MIOCENE SANDSTONE PLAY

PLAY DEFINITION

The Lower Miocene Sandstone play of the Cortes-Velero-Long assessment area is a conceptual play consisting of oil and associated gas accumulations in lower Miocene sandstones. The play exists over most of the assessment area where it encompasses an area of about 3,400 square miles (fig. 136). The depth to reservoir rocks in the play ranges from 1,000 to 4,500 feet and averages 3,000 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The primary potential petroleum source rocks for this play are Paleogene mudstones and shales (fig. 137). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks (Vedder, 1987). The geothermal gradient in the Cortes-Velero-Long assessment area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. However, potential source rocks are thin in the area, and the volume of generated oil and gas may therefore be small.

Potential reservoir rocks in this play are lower Miocene sandstones (fig. 137). Lower Miocene strata penetrated in the wells on Dall, Tanner, and Cortes banks are described as porous and fine- to medium-grained sandstones with log-derived porosities of 23 to 32 percent and with good permeability. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the Cortes-Velero-Long assessment area. Based on seismic mapping, rocks inferred to be of early Miocene age are areally extensive throughout the assessment area; this stratigraphic unit has an average thickness of about 1,500 feet and a maximum thickness estimated to be 2,500 feet.

The dominant trap types in this play are small to large, low-relief anticlinal folds and normal-fault traps.

EXPLORATION

Most of the exploratory wells on Dall, Tanner, and Cortes banks penetrated rocks similar to those included in this play; analog data from these wells have been used in the assessment of this play. No appreciable shows of hydrocarbons were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and

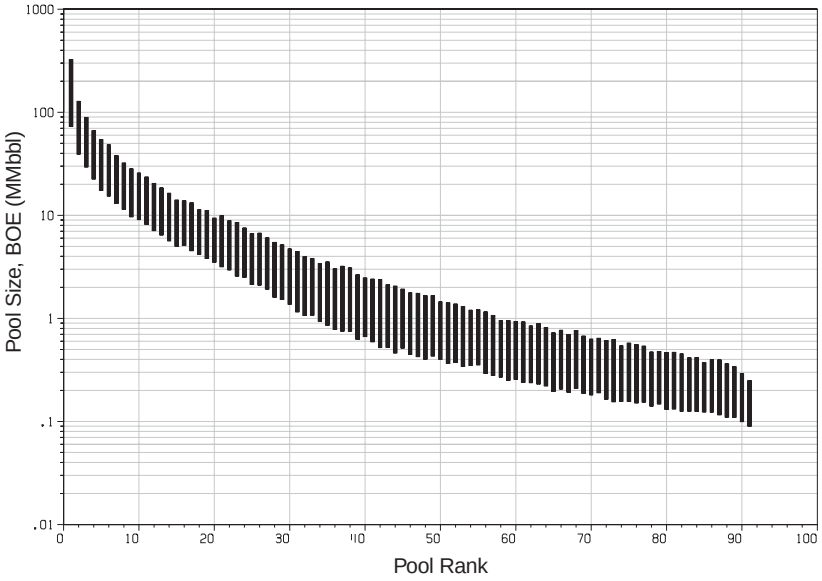

Figure 141. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Lower Miocene Sandstone play, Cortes-Velero-Long assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

weak gas shows) were encountered in lower Miocene and other rocks in some of the wells.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Conservatively reduced analog data from Vaqueros, Sespe, and Alegria producing zones in the offshore Santa Barbara-Ventura basin were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 242 MMbbl of oil and 659 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 91 pools with sizes ranging from approximately 90 Mbbl to 325 MMbbl of combined oil-equivalent resources (fig. 141). The low, mean, and high estimates of resources in the play are listed in table 46.

PALEOGENE-CRETACEOUS SANDSTONE PLAY

PLAY DEFINITION

The Paleogene-Cretaceous Sandstone play of the Cortes-Velero-Long assessment area is a conceptual play consisting of oil and associated gas accumulations in Upper Cretaceous and Paleogene sandstones. The play exists over most of the assessment area where it encompasses an area of about 4,100 square miles (fig. 136). The depth to reservoir rocks in the play ranges from 4,000 to 8,000 feet and averages 5,500 feet below the seafloor.

PETROLEUM GEOLOGIC CHARACTERISTICS

The primary potential petroleum source rocks for this play are Paleogene mudstones and shales (fig. 137). Oligocene and Eocene rocks of adequate to excellent source quality were penetrated by the deep stratigraphic test well (OCS-CAL 75-70 No. 1) on Cortes bank. The total organic carbon content of samples from this well is 3.3 to 4.3 weight percent in Oligocene rocks and 0.4 to 2.7 weight percent in Eocene rocks; Upper Cretaceous shales containing 0.4 to 0.6 percent total organic carbon are not considered to be potential source rocks (Vedder, 1987). The geothermal gradient in this area is unknown; however, if a moderate (1.8 to 2.0 °F per 100 feet) geothermal gradient is assumed to have existed, petroleum generation may have occurred in these rocks under current burial conditions. However, potential source rocks are thin in the area, and the volume of generated oil and gas may therefore be small.

Potential reservoir rocks in this play are Paleogene and Cretaceous sandstones (fig. 137). Paleogene

strata penetrated in the wells on Dall, Tanner, and Cortes banks are described as porous and fine- to coarse-grained sandstones. Log-derived porosities range from 23 to 30 percent in Oligocene samples, from 10 to 25 percent in Eocene samples, and from 6 to 14 percent in Upper Cretaceous samples. The proportion of sandstone within the total section is quite high; on average, sandstone composes approximately 50 percent of the total Paleogene section. Similar rocks of potentially good to excellent reservoir quality are presumed to exist in the Cortes-Velero-Long assessment area. Based on seismic mapping and well correlations, rocks inferred to be of Paleogene and Cretaceous age are areally extensive throughout the Cortes-Velero-Long assessment area; this stratigraphic unit has an average thickness of about 2,000 feet and a maximum thickness estimated to be 3,500 feet.

The dominant trap types in this play are small to large, low-relief anticlinal folds and normal-fault traps.

EXPLORATION

All of the exploratory wells on Dall, Tanner, and Cortes banks penetrated Paleogene rocks similar to those included in this play, and most of the wells penetrated Cretaceous rocks; analog data from these wells have been used in the assessment of this play. No appreciable shows of hydrocarbons were encountered in the wells; however, weak indications of hydrocarbons (oil staining, minor fluorescence, and weak gas shows) were encountered in Paleogene, Cretaceous, and other rocks in some of the wells.

RESOURCE ESTIMATES

Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the play have been developed using the subjective assessment method with a combination of play-specific and analog data. Select data used to develop the resource estimates are shown in appendix C.

The area and number of prospects in the play were estimated from seismic mapping. Analog data from Cretaceous, Eocene, and Oligocene producing zones in the Santa Barbara-Ventura, Los Angeles, and San Joaquin basins were used to estimate the net-pay thickness, oil recovery factor, and gas-to-oil ratio for this play.

As a result of this assessment, the play is estimated to contain 169 MMbbl of oil and 442 Bcf of associated gas (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in as many as 64 pools with sizes ranging from approximately 105 Mbbl to 340 MMbbl of combined oil-equivalent resources (fig. 142). The low, mean, and high estimates of resources in the play are listed in table 46.

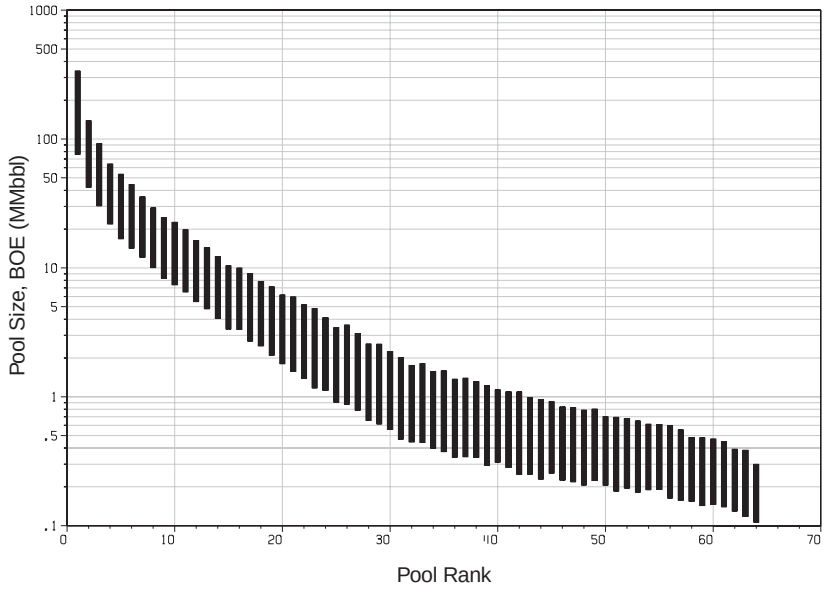

Figure 142. *Pool-size rank plot of estimated undiscovered conventionally recoverable resources of the Paleogene-Cretaceous Sandstone play, Cortes-Velero-Long assessment area. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*